

### US009196818B2

### (12) United States Patent

### Yamane et al.

### (54) BOUNDARY ACOUSTIC WAVE DEVICE

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U.S.C. 154(b) by 141 days.

This patent is subject to a terminal dis-

claimer.

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(60) Division of application No. 12/913,847, filed on Oct. 28, 2010, now Pat. No. 8,436,510, which is a continuation of application No. PCT/JP2009/001476, filed on Mar. 31, 2009.

### (30) Foreign Application Priority Data

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(51) **Int. Cl.** 

 H01L 41/187
 (2006.01)

 H01L 41/18
 (2006.01)

 H03H 9/02
 (2006.01)

(52) U.S. Cl.

(10) Patent No.:

US 9,196,818 B2

(45) **Date of Patent:** 

\*Nov. 24, 2015

### 58) Field of Classification Search

CPC . H01L 41/18; H01L 41/1871; H01L 41/1873;

H03H 9/0222

USPC ...... 310/313 R, 313 A, 313 B, 313 C, 313 D,

310/358; 252/62.9 R, 62.9 PZ

See application file for complete search history.

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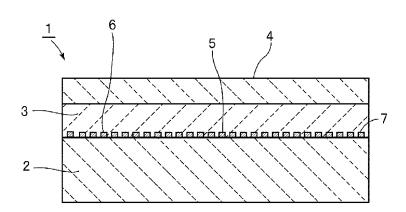
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### (57) ABSTRACT

A boundary acoustic wave device includes an LiTaO $_3$  piezoelectric substrate, a first dielectric medium layer disposed on the piezoelectric substrate, a second dielectric medium layer disposed on the first medium layer and having a sound velocity different from the first medium layer, and an interdigital electrode disposed at the boundary between the piezoelectric substrate and the first medium layer. The sound velocity of the first medium layer is less than the sound velocity of LiTaO $_3$ . The sound velocity of the second medium layer is greater than the sound velocity of LiTaO $_3$ . The inequality  $(h/\lambda) \times a \le 0.05$  is satisfied, where H is the thickness of the first medium layer, h is the thickness of the interdigital electrode,  $\lambda$  is the period of electrode fingers of the interdigital electrode, and a is the ratio of the density of a metal of the interdigital electrode to the density of Au.

### 8 Claims, 16 Drawing Sheets



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FIG. 1A

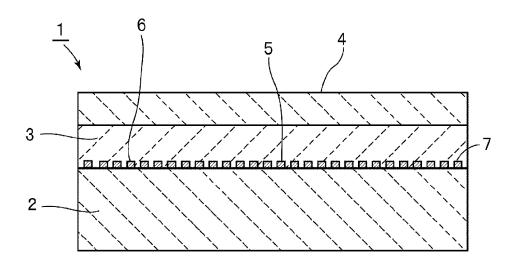
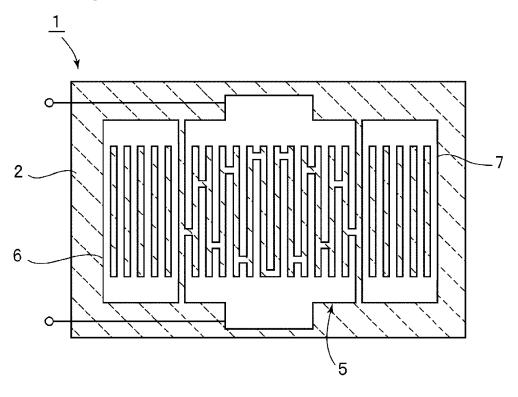
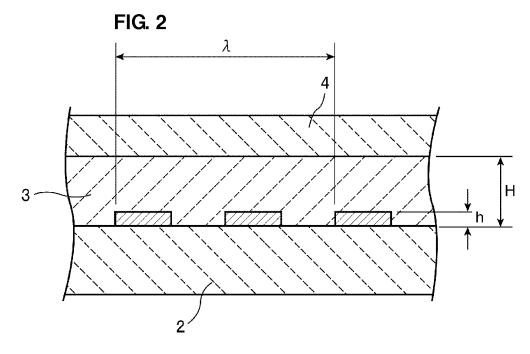
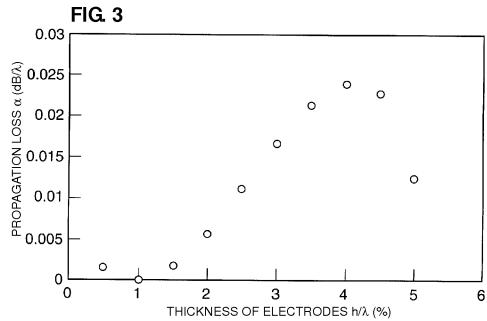
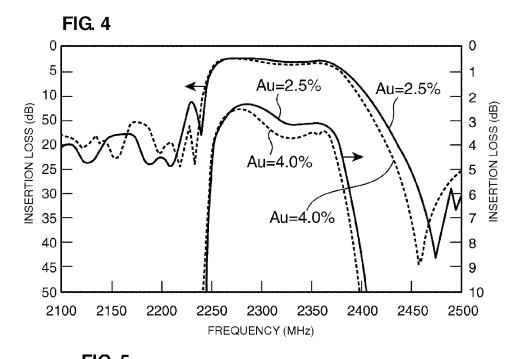


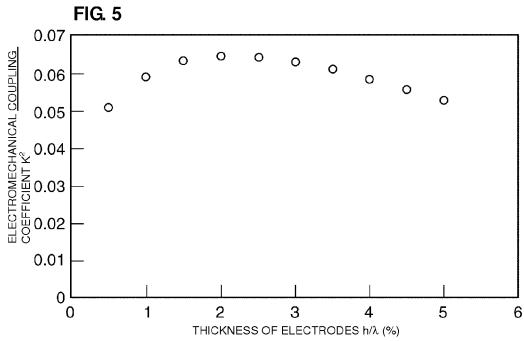
FIG. 1B

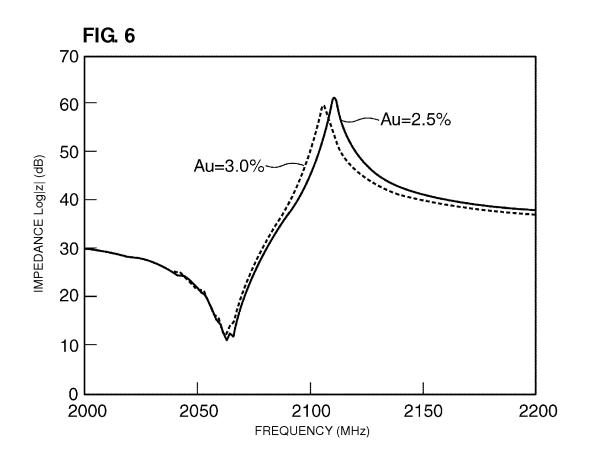


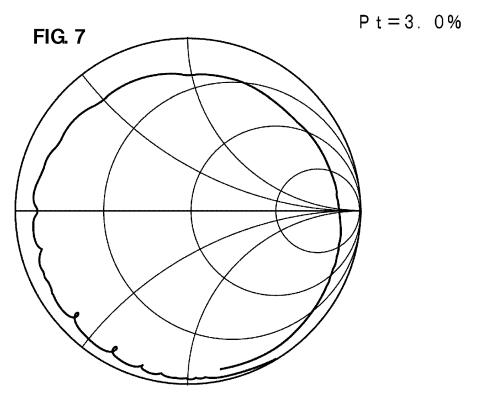


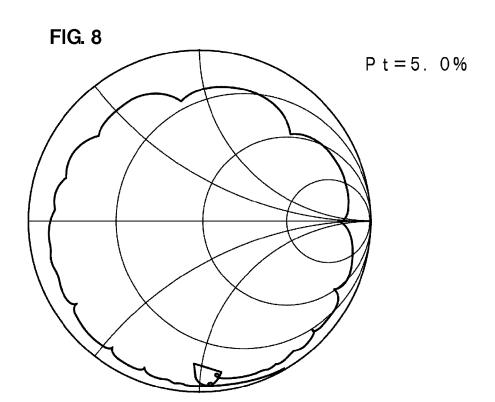












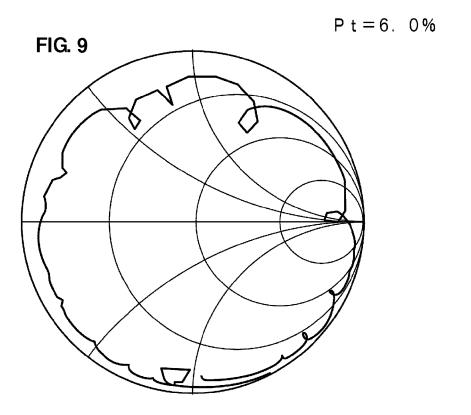


FIG. 10

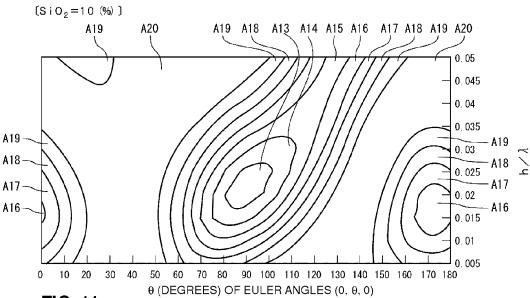
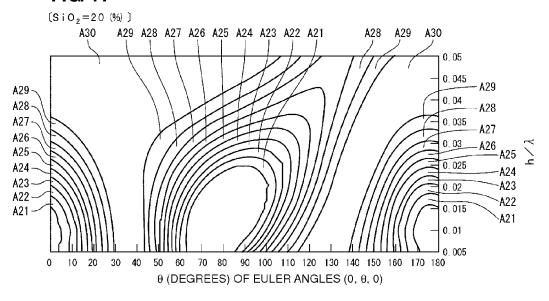


FIG. 11



**FIG. 12** 

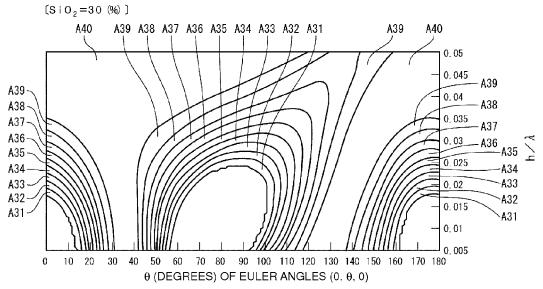


FIG. 13

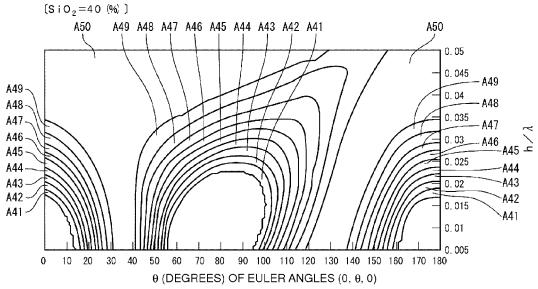


FIG. 14

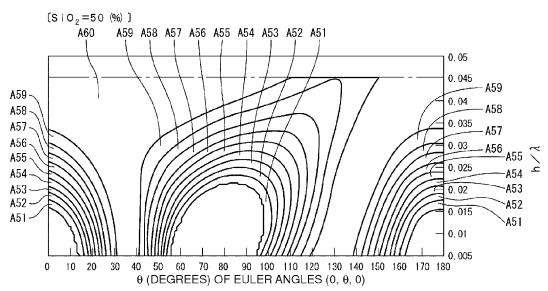


FIG. 15

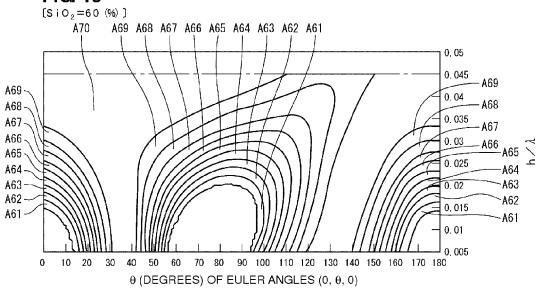
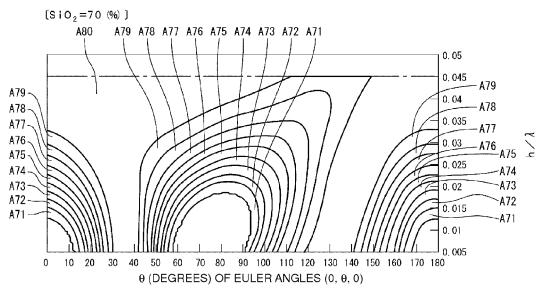


FIG. 16



**FIG. 17** 

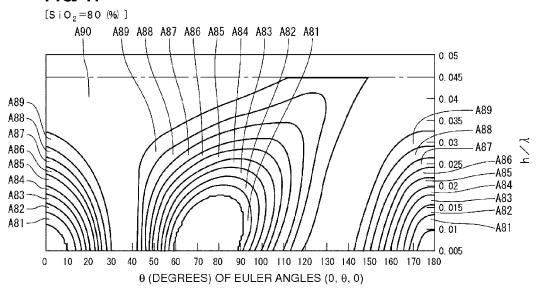


FIG. 18

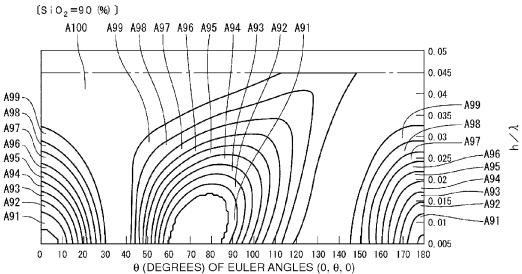


FIG. 19

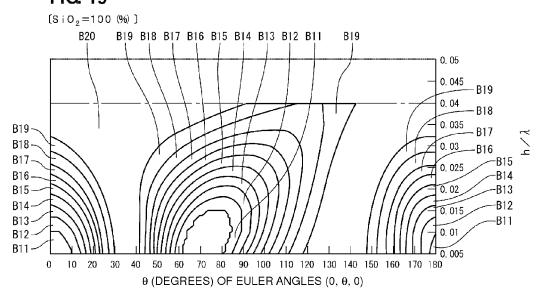


FIG. 20

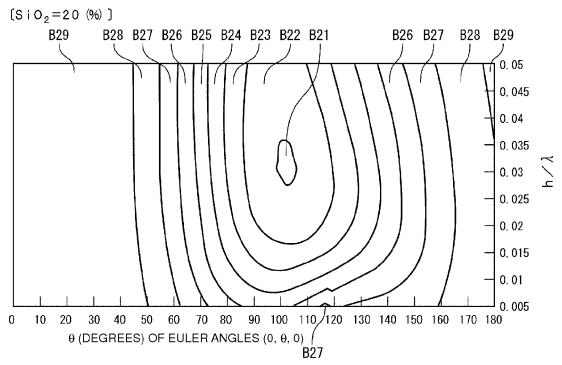


FIG. 21

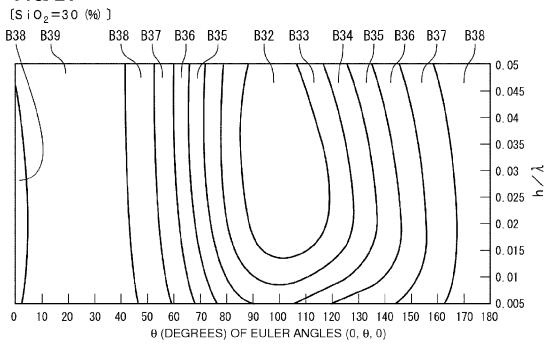
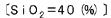


FIG. 22



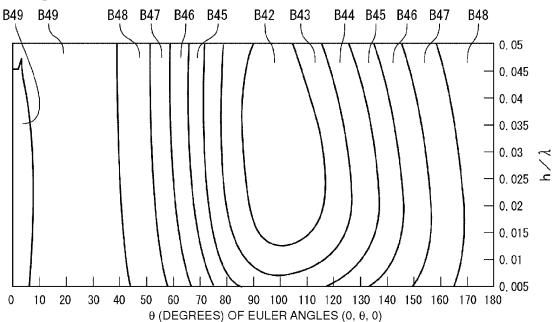


FIG. 23

 $[SiO_2 = 50 (\%)]$ 

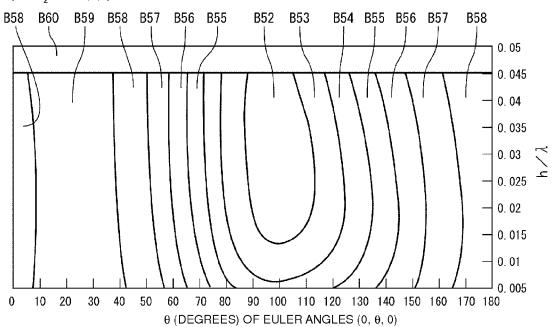


FIG. 24

 $[SiO_2=60 \%]$ 

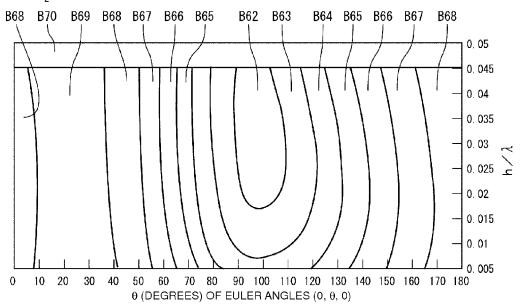


FIG. 25

 $[SiO_2=70 (\%)]$ 

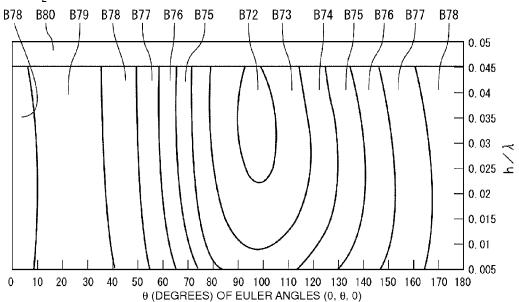


FIG. 26

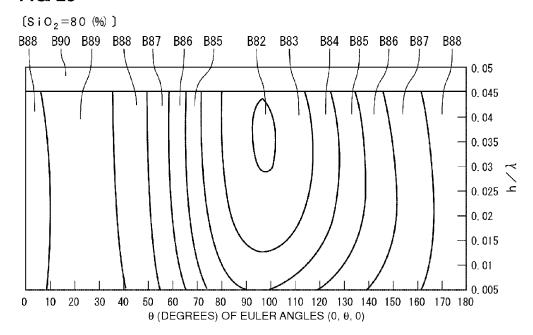


FIG. 27

 $[SiO_2=90 (\%)]$ 

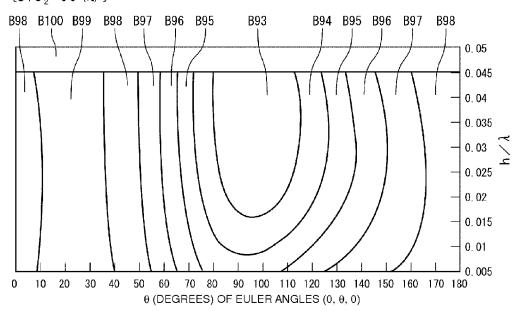
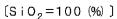
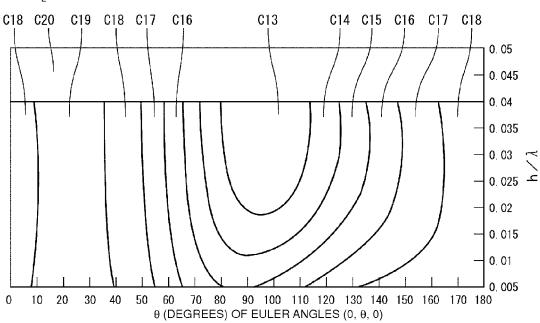
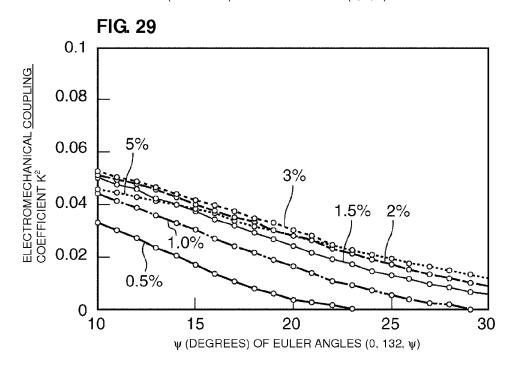
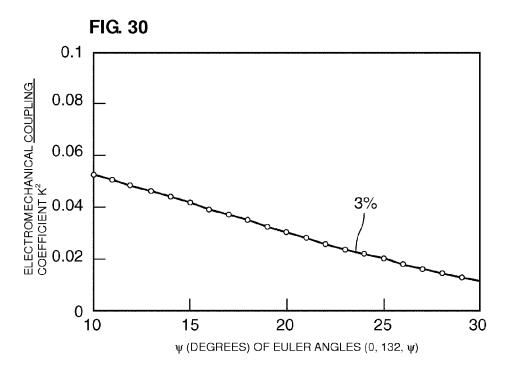


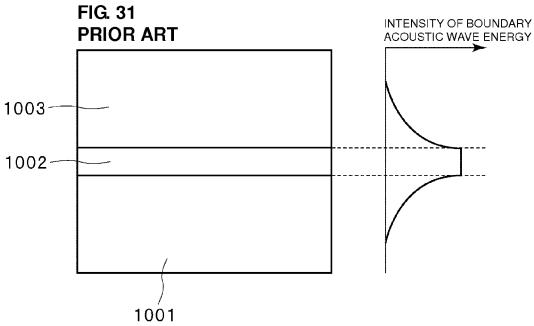
FIG. 28











### BOUNDARY ACOUSTIC WAVE DEVICE

### BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to boundary acoustic wave devices for use in, for example, resonators and filters, and particularly, to a boundary acoustic wave device having a three-medium structure in which a first medium layer and a second medium layer are arranged on a piezoelectric substrate made of LiTaO<sub>3</sub>.

### 2. Description of the Related Art

In recent years, boundary acoustic wave devices have been substituted for surface acoustic wave devices and have been attracting much attention. The boundary acoustic wave 15 devices do not require packages having cavities. Therefore, the use of the boundary acoustic wave devices is effective to achieve compact resonators and filters.

WO 98/52279 discloses an exemplary boundary acoustic wave device having a three-medium structure in which a first 20 medium layer and a second medium layer are arranged on a piezoelectric substrate. With reference to FIG. 31, interdigital electrodes (not shown) are arranged on a piezoelectric substrate 1001 and a polycrystalline silicon oxide layer defining a first medium layer 1002 and a polycrystalline silicon layer 25 defining a second medium layer 1003 are arranged on the piezoelectric substrate 1001. The IDT electrodes are arranged at the interface between the piezoelectric substrate and the polycrystalline silicon oxide layer.

The presence of the polycrystalline silicon layer allows the 30 energy of a boundary acoustic wave excited by the IDT electrodes to be confined in the first medium layer 1002, which is made of the polycrystalline silicon oxide layer, as shown in FIG. 21

Even if the quality of the polycrystalline silicon layer is deteriorated, electrical properties of the boundary acoustic wave device are unlikely to be deteriorated. Since the polycrystalline silicon oxide layer and the polycrystalline silicon layer protect the IDT electrodes, the reliability of the boundary acoustic wave device is outstanding. The use of the three-medium structure is particularly effective for higher frequencies

WO 98/52279 does not address changes in properties depending on the thickness of the IDT electrodes. However, it has been determined that when IDT electrodes have an 45 increased thickness or are made of a high-density metal, an undesired transverse-mode ripple is excited in such a conventional boundary acoustic wave device as disclosed in WO 98/52279. The three-medium structure, which includes LiTaO<sub>3</sub> as disclosed in WO 98/52279, is not always capable 50 of obtaining good properties.

### SUMMARY OF THE INVENTION

To overcome the problems described above, preferred 55 embodiments of the present invention provide a boundary acoustic wave device which has a three-medium structure including a piezoelectric substrate made of single-crystalline  $\text{LiTaO}_3$  and which suppresses transverse-mode ripples appearing in the frequency response, reduces the propagation 60 constant  $\alpha$ , and increases the electromechanical coupling coefficient  $K^2$  so as to expand the pass band.

A preferred embodiment of the present invention provides a boundary acoustic wave device that includes a piezoelectric substrate made of single-crystalline LiTaO<sub>3</sub>, a first medium 65 layer which is disposed on the piezoelectric substrate and which is made of a dielectric material, a second medium layer 2

which is disposed on the first medium layer and which is made of a dielectric material having a sound velocity different from that of the dielectric material of the first medium layer, and at least one interdigital electrode disposed at the boundary between the piezoelectric substrate and the first medium layer. The sound velocity of the first medium layer is less than the sound velocity of LiTaO3. The sound velocity of the second medium layer is greater than the sound velocity of LiTaO3. The inequality (h/ $\lambda$ )×a $\leq$ 0.05 is satisfied, where H is the thickness of the first medium layer, h is the thickness of the interdigital electrode,  $\lambda$  is the period of electrode fingers of the interdigital electrode, and a is the ratio of the density of a metal of the interdigital electrode to the density of Au.

In the boundary acoustic wave device according to a preferred embodiment of the present invention, the dielectric material of the first medium layer is not particularly limited and is preferably  $\mathrm{SiO}_2$ , for example. This enables the absolute value of the temperature coefficient of frequency of the boundary acoustic wave device to be small because  $\mathrm{LiTaO}_3$  has a negative temperature coefficient of frequency and  $\mathrm{SiO}_2$  has a positive temperature coefficient of frequency. Therefore, changes in properties due to changes in temperature are reduced

In the boundary acoustic wave device according to a preferred embodiment of the present invention, the dielectric material of the second medium layer is not particularly limited and is preferably at least one material selected from the group consisting of SiN, SiON, AlN, AlO, Si, SiC, diamond-like carbon, and polysilicon, for example. In this case, a boundary acoustic wave can be confined in an SiO<sub>2</sub> layer by a waveguide effect.

When the LiTaO<sub>3</sub> has Euler angles (0°±5°,  $\theta$ , 0°±25°), the normalized thickness (h/ $\lambda$ )×a of the interdigital electrode is preferably within one of the ranges shown in Tables 1 to 10 below with respect to the value of H/ $\lambda$  and the value of  $\theta$ .

### TABLE 1

For [0.	$0.5 \le H/\lambda \le 0.15$
When $0 \le \theta \le 75.5$	$(h/\lambda)$ X a is 0.005 to 0.05.
When $75.5 \le \theta < 76.5$	$(h/\lambda)$ X a is 0.005 to 0.014 or 0.021
***	to 0.05.
When $76.5 \le \theta < 77.5$	$(h/\lambda)$ X a is 0.005 to 0.014 or 0.022
When $77.5 \le \theta < 78.5$	to 0.05. (h/λ) X a is 0.005 to 0.0135 or
when //.3 ≤ 6 < /8.3	0.023 to 0.05.
When $78.5 \le \theta < 79.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or 0.024
When 70.5 = 0 175.5	to 0.05.
When $79.5 \le \theta \le 80.5$	(h/λ) X a is 0.005 to 0.013 or 0.025
	to 0.05.
When $80.5 \le \theta \le 81.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or
	0.0255 to 0.05.
When $81.5 \le \theta \le 82.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or 0.026
	to 0.05.
When $82.5 \le \theta \le 83.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or
When $83.5 \le \theta \le 84.5$	0.0265 to 0.05. (h/λ) X a is 0.005 to 0.013 or 0.027
W Hell 85.5 ≤ 6 < 84.5	to 0.05.
When $84.5 \le \theta \le 85.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or
When 64.5 2 6 4 65.5	0.0275 to 0.05.
When $85.5 \le \theta \le 86.5$	(h/λ) X a is 0.005 to 0.013 or 0.028
	to 0.05.
When $86.5 \le \theta \le 87.5$	(h/λ) X a is 0.005 to 0.013 or
	0.0285 to 0.05.
When $87.5 \le \theta \le 88.5$	$(h/\lambda)$ X a is 0.005 to 0.0135 or
	0.029 to 0.05.
When $88.5 \le \theta < 90.5$	$(h/\lambda)$ X a is 0.005 to 0.0135 or
When $90.5 \le \theta < 91.5$	0.0295 to 0.05.
W Hell 30.3 ≥ 0 < 31.3	(h/λ) X a is 0.005 to 0.014 or 0.03 to 0.05.
When $91.5 \le \theta < 92.5$	$(h/\lambda)$ X a is 0.005 to 0.014 or
11 Hell 71.5 2 0 \ 72.5	0.0305 to 0.05.
	0.0303 60 0.03.

# TABLE 1-00

When 92.5 ± 0 ≤ 91.5   When 92.5 ± 0 ≤ 101.5   When 102.5 ± 0	TABLE 1-continued			TABLE 2-continued		
When 93.5 = 0 < 91.5 (A) X is in 0.035 to 0.05. When 93.5 = 0 < 95.5 (A) X is in 0.035 to 0.015 or 0.	For [	$[0.05 \le H/\lambda \le 0.15]$		Fo	$r [0.15 \le H/\lambda < 0.25]$	
When 93.5 = 0 < 91.5 (A) X is in 0.035 to 0.05. When 93.5 = 0 < 95.5 (A) X is in 0.035 to 0.015 or 0.	When 92.5 $< \theta < 93.5$	(h/λ) X a is 0.005 to 0.0145 or		When 67.5 < θ < 68.5	(h/λ) X a is 0.026 to 0.05	
When 93.5 e 0 < 91.5  When 93.5 e 0 < 91.5  When 95.5 e 0 < 92.5			5			
When 94.5 ≈ 0 < 95.5	When $93.5 \le \theta < 94.5$	$(h/\lambda) X$ a is 0.005 to 0.0145 or		When $69.5 \le \theta < 70.5$	$(h/\lambda)$ X a is 0.027 to 0.05.	
When 95.5 ≈ 6 < 96.5 (a) (A) X is in 0.005 to 0.015 or 0.015 or 0.015 to 1.005 to 0.015 or 0.015 to 0.015 to 0.015 or 0.015 to 0.015 or 0.015 to 0.015 or 0.015 to 0.015 to 0.015 or 0.015 to 0.015 or 0.015 to 0.015 or 0.015 to 0.015 to 0.015 or 0.015 to 0.015 or 0.015 to 0.015 to 0.015 to 0.015 to 0.015 or 0.015 to 0.015 to 0.015 or 0.015 to 0						
When 9.5. ≈ 0 < 9.6.5. When 9.5. ≈ 0 < 9.6.5. When 9.5. ≈ 0 < 9.7.5. When 9.5. ≈ 0 < 9.7.5	When $94.5 \le \theta < 95.5$					
O.   O.   O.   O.   O.   O.   O.   O.	WII 055 0 1055					
When 90.5 ≈ 0 < 9.75.  When 90.5 ≈ 0 < 9.95.  When 90.5 ≈ 0 < 10.15.  When 90.5 ≈ 0 < 10.15.  When 10.5 ≈ 0 < 10.25.  When 10.5 ≈	When $95.5 \le \theta < 96.5$					
When 97.5 ≤ 8 < 98.5   \$\( \text{Q}_{1}\text{X}_{2}\text{ si 0.0015 to 0.015 co 0.015} \)   When 98.5 ≤ 8 < 9 < 95.	When 065 - 9 < 075		10			
When 97.5 ≤ 6 < 98.5 (b) X a is 0.035 to 0.0165 or 0.0165 or 0.05 (b) X b) X a is 0.035 to 0.05 (b) X A is 0.005 to 0.017 or 0.032 by 0.05 (b) X A is 0.005 to 0.017 or 0.032 by 0.05 (b) X A is 0.005 to 0.017 or 0.032 by 0.05 (b) X A is 0.005 to 0.018 or 0.05 (b) X A is 0.005 to 0.018 or 0.05 (b) X A is 0.005 to 0.018 or 0.05 (b) X A is 0.005 to 0.018 or 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or 0.033 to 0.05 (b) X A is 0.005 to 0.005 or	when 90.3 ≤ 0 < 97.3	· ,				
When 98.5 ≈ 0 < 9.95.	When $97.5 < \theta < 98.5$					
When 98.5 ≈ 0 < 99.5 (b) A X is in 0.005 to 0.017 or 0.022 to 0.05. (b) A X is in 0.005 to 0.018 or 0.025 to 0.05. (b) A X is in 0.035 to 0.018 or 0.025 to 0.05. (b) A X is in 0.035 to 0.018 or 0.025 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05 or 0.035 to 0.05. (b) A X is in 0.035 to 0.055 or 0.035 to 0.05 or 0.0	When you a division					
Table 2	When $98.5 \le \theta < 99.5$					
When 10.5 ≈ θ < 10.5 (b) X a is 0.003 to 0.015 or 0.015			1.5		$(h/\lambda)$ X a is 0.0325 to 0.05.	
When 101.5 ≈ 0 < 102.5 (b) $3$ , $3$ x is 0.005 to 0.018 or When 101.5 ≈ 0 < 102.5 (b) $3$ , $3$ x is 0.005 to 0.018 or When 102.5 ≈ 0 < 103.5 (b) $3$ , $3$ x is 0.005 to 0.018 or When 102.5 ≈ 0 < 103.5 (b) $3$ , $3$ x is 0.005 to 0.018 or When 103.5 ≈ 0 < 104.5 (b) $3$ , $3$ x is 0.005 to 0.019 or 0.033 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.05. (b) $3$ x is 0.005 to 0.025 to 0.035 to 0.025 to 0.	When $99.5 \le \theta < 100.5$	$(h/\lambda)$ X a is 0.005 to 0.0175 or	13	When $92.5 \le \theta < 97.5$	$(h/\lambda)$ X a is 0.033 to 0.05.	
When 101.5 ≈ 0 < 102.5   (b/λ) X is is 0.005 to 0.018 to 0.018 to 0.033 to 0.05.						
When 101.5 ≈ 0 < 102.5	When $100.5 \le \theta \le 101.5$			When $98.5 \le \theta < 99.5$		
When 10.2.5 ≈ 0 < 10.5.5  When 10.3.5 ≈ 0 < 10.4.5  When 10.3.5 ≈ 0 < 10.4.5  When 10.3.5 ≈ 0 < 10.4.5  When 10.3.5 ≈ 0 < 10.5  When 10.4.5 ≈ 0 < 10.5  When 10.5.5 ≈ 0 < 10.5  When 10.5 ≈ 0	When $101.5 \le \theta \le 102.5$			When $99.5 \le \theta \le 100.5$		
When 103.5 ≤ 0 < 10.45. When 104.5 ≤ 0 < 10.45. When 104.5 ≤ 0 < 10.55. When 104.5 ≤ 0 < 10.55. When 105.5 ≤ 0 < 10.65. When 105.5 ≤ 0 < 10.65. When 105.5 ≤ 0 < 10.65. When 106.5 ≤ 0 < 10.75. When 107.5 ≤ 0 < 10.85. When 108.5 ≤ 0 < 10.95. When 110.5 ≤ 0 < 111.5 W	WI 100.5 0 1100.5		20	XXII 100.5 0 1101.5		
When 103.5 ≈ 0 < 104.5	When $102.5 \le \theta \le 103.5$	· /	20	When $100.5 \le \theta \le 101.5$		
When $104.5 \le 0 \le 105.5$ (b), $3$ ) X a is 0.005 to 0.0225 or 0.033 to 0.05.   When $105.5 \le 0 \le 106.5$ (b), $3$ ) X a is 0.005 to 0.0215 or 0.033 to 0.05.   When $106.5 \le 0 \le 107.5$ (b), $3$ ) X a is 0.005 to 0.0225 or 0.033 to 0.05.   When $107.5 \le 0 \le 108.5$ (b), $3$ ) X a is 0.005 to 0.0225 or 0.033 to 0.05.   When $107.5 \le 0 \le 108.5$ (b), $3$ ) X a is 0.005 to 0.0225 or 0.033 to 0.05.   When $108.5 \le 0 \le 109.5$ (b), $3$ ) X a is 0.005 to 0.0226 or 0.033 to 0.05.   When $109.5 \le 0 \le 110.5$ (b), $3$ ) X a is 0.005 to 0.0226 or 0.033 to 0.05.   When $109.5 \le 0 \le 110.5$ (b), $3$ ) X a is 0.005 to 0.0226 or 0.033 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.028 or 0.032 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.028 or 0.032 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.028 or 0.032 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.0295 or 0.030 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.0295 or 0.030 to 0.05.   When $111.5 \le 0 \le 111.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 11.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 11.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b), $3$ ) X a is 0.005 to 0.05.   When $111.5 \le 0 \le 1.5$ (b),	When $103.5 \le \theta \le 104.5$	$(h/\lambda)$ X a is 0.005 to 0.0195 or		When $101.5 \le \theta \le 102.5$	$(h/\lambda) X$ a is 0.005 to 0.0075 or	
When $105.5 \approx 0 = 106.5$ (bd.) X a is $0.005$ to $0.0215$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 107.5$ (bd.) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 108.5$ (bd.) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 108.5$ (bd.) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 109.5$ (bd.) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 109.5$ (bd.) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ . When $106.5 \approx 0 = 109.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $106.5 \approx 0 = 110.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $106.5 \approx 0 = 110.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $106.5 \approx 0 = 110.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $110.5 \approx 0 = 111.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $110.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.0226$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.025$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.025$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.025$ or $0.0325$ to $0.05$ . When $111.5 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.005$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.003$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.003$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.003$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.003$ to $0.05$ . When $1.05 \approx 0 = 112.5$ (bd.) X a is $0.$	When $104.5 \le \theta \le 105.5$			When $102.5 \le \theta \le 103.5$		
When 106.5 ≤ θ < 107.5 When 107.5 ≤ θ < 108.5 When 108.5 ≤ θ < 109.5 When 108.5 ≤ θ < 109.5 When 108.5 ≤ θ < 101.5 When 108.5 ≤ θ < 101.5 When 108.5 ≤ θ < 101.5 When 109.5 ≤ θ < 101.5 When 109.5 ≤ θ < 101.5 When 11.5 ≤ θ < 111.5 When 109.5 ≤ θ < 101.5 When 11.5 ≤ θ < 112.5 When 11.5 ≤ θ < 112.5 When 11.5 ≤ θ < 10.5 When 10.5 ≤ θ < 10.5 When 10.5 ≤ θ < 10.5 When 10.5 ≤ θ < 10.5 When 11.5 ≤ θ < 10.5 When 10.5 ≤ θ < 10.		0.033 to 0.05.			0.0335 to 0.05.	
When $106.5 \le \theta < 107.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.0225$ or $0.033$ to $0.05$ .  When $107.5 \le \theta < 108.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.0235$ or $0.033$ to $0.05$ .  When $108.5 \le \theta < 109.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.024$ or $0.025$ to $0.05$ .  When $109.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.024$ or $0.025$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.024$ or $0.035$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.025$ or $0.035$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.025$ or $0.035$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.025$ or $0.035$ to $0.05$ .  When $111.5 \le \theta < 112.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $111.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $112.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 180$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \ge \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \ge \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \ge \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X a is $0.005$ to $0.05$ .  When $110.5 \le \theta < 110.5$ ( $h/\lambda$ ) X	When $105.5 \le \theta \le 106.5$		25	When $103.5 \le \theta \le 104.5$		
0.033 to 0.05.	Wilson 106.5 + 0 < 107.5			When 1045 = 0 < 1055		
When $107.5 \le 0 < 108.5$ (b/h) X a is 0.005 to 0.0235 or 0.033 to 0.05. (b/h) X a is 0.005 to 0.024 or 0.033 to 0.05. (b/h) X a is 0.005 to 0.024 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.024 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.026 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.026 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.026 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.026 or 0.0325 to 0.05. (b/h) X a is 0.005 to 0.028 or 0.032 to 0.05. (b/h) X a is 0.005 to 0.028 or 0.032 to 0.05. (b/h) X a is 0.005 to 0.0295 or 0.030 to 0.05. (b/h) X a is 0.005 to 0.05. (b/h) X a is 0.023 to	when 100.5 ≤ 6 < 107.5			When 104.3 \( \) \( \) 103.3	· /	
When $108.5 ≤ 0 < 109.5$	When $107.5 \le \theta \le 108.5$			When $105.5 \le \theta \le 106.5$		
When 109.5 ≈ 0 < 110.5 ( $h/h$ ) X a is 0.005 to 0.026 or 0.0325 to 0.05. ( $h/h$ ) X a is 0.005 to 0.0125 or 0.0325 to 0.05. ( $h/h$ ) X a is 0.005 to 0.026 or 0.0325 to 0.05. ( $h/h$ ) X a is 0.005 to 0.028 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.028 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.025 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.025 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.05. ( $h/h$ ) X a is 0.005 to 0.05. ( $h/h$ ) X a is 0.005 to 0.05. ( $h/h$ ) X a is 0.005 to 0.05. ( $h/h$ ) X a is 0.005 to 0.05. ( $h/h$ ) X a is 0.005 to 0.0145 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.015 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.015 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.015 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.015 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.015 or 0.033 to 0.05. ( $h/h$ ) X a is 0.005 to 0.0175 or 0.0325 to 0.05. ( $h/h$ ) X a is 0.005 to 0.019 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.019 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.019 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.019 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005 to 0.019 or 0.032 to 0.05. ( $h/h$ ) X a is 0.005		` /				
When 109.5 ≤ θ < 110.5   (bλ) X a is 0.005 to 0.026 or 0.0325 to 0.05.  When 110.5 ≤ θ < 111.5   (bλ) X a is 0.005 to 0.028 or 0.032 to 0.05.  When 111.5 ≤ θ < 112.5   (bλ) X a is 0.005 to 0.0295 or 0.0305 to 0.05.  When 111.5 ≤ θ < 112.5   (bλ) X a is 0.005 to 0.0295 or 0.0305 to 0.05.  When 112.5 ≤ θ < 180   (bλ) X a is 0.005 to 0.0295 or 0.0305 to 0.05.  When 112.5 ≤ θ < 180   (bλ) X a is 0.005 to 0.0295 or 0.0305 to 0.05.  When 112.5 ≤ θ < 180   (bλ) X a is 0.005 to 0.025 to 0.05.  When 112.5 ≤ θ < 110.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 112.5 ≤ θ < 111.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 112.5 ≤ θ < 111.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 111.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 113.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 113.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.0145 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.015 or 0.033 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤ θ < 115.5   (bλ) X a is 0.005 to 0.05.  When 115.5 ≤	When $108.5 \le \theta \le 109.5$	· · · · · ·	30	When $106.5 \le \theta \le 107.5$		
When $110.5 \le \theta < 111.5$ (b) (λ) X a is 0.005 to 0.028 or 0.032 to 0.05.  When $111.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.0295 or 0.035 to 0.05.  When $111.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.0295 or 0.035 to 0.05.  When $112.5 \le \theta < 180$ (b) (λ) X a is 0.005 to 0.0295 or 0.035 to 0.05.  When $112.5 \le \theta < 180$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.0175 or 0.0325 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.0175 or 0.0325 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.019 or 0.032 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \le \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X a is 0.005 to 0.05.  When $112.5 \ge \theta < 112.5$ (b) (λ) X	When 100 5 < A < 110 5			When $107.5 \le \theta \le 108.5$		
When 110.5 ≤ θ < 111.5. (h/λ) X a is 0.005 to 0.028 or 0.032 to 0.025 to 0.035 to 0.025 to 0.035 to 0.025 to 0.035 to 0.05. (h/λ) X a is 0.005 to 0.015 to 0.05. (h/λ) X a is 0.005 to 0.015 to 0.05. (h/λ) X a is 0.005 to 0.015 to 0.0175 or 0.0325 to 0.05. (h/λ) X a is 0.005 to 0.019 or 0.032 to 0.05. (h/λ) X a is 0.005 to 0.019 or 0.032 to 0.05. (h/λ) X a is 0.005 to 0.015 to 0.05. (h/λ) X a is 0.005 to 0.05. (h/λ) X a is 0.005 to 0.05. (h/λ) X a is 0.0235 to 0.05. (h/λ) X a is 0	When 109.3 \( \) \( \) 110.3	· · · · · · · · · · · · · · · · · · ·		With 100 5 - 0 < 100 5		
When 111.5 ≤ θ < 112.5	When $110.5 \le \theta \le 111.5$	* *		When 108.5 ≤ 0 < 109.5		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	When 111 5 - 9 < 112 5		35	When $109.5 \le \theta \le 110.5$	$(h/\lambda)$ X a is 0.005 to 0.0145 or	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	When 111.5 ≤ 0 < 112.5			When 110 5 < θ < 111 5		
$TABLE \ 2 \\ \hline \\ TABLE 2 \\ \hline \\ For [0.15 \le H/\lambda < 0.25] \\ \hline \\ When 1.2.5 \le 0 < 113.5 \\ \hline \\ When 1.13.5 \le 0 < 114.5 \\ \hline \\ When 1.13.5 \le 0 < 114.5 \\ \hline \\ When 1.13.5 \le 0 < 114.5 \\ \hline \\ When 1.13.5 \le 0 < 114.5 \\ \hline \\ When 1.13.5 \le 0 < 114.5 \\ \hline \\ When 1.14.5 \le 0 < 115.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \le 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5 \ge 0 < 3.5 \\ \hline \\ When 1.15.5$	When $112.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.005 to 0.05.		Wildliff Told = 0 Fiftis		
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $			_	When $111.5 \le \theta < 112.5$		
TABLE 2  When 113.5 ≤ 0 < 114.5   (h/λ) X a is 0.005 to 0.021 sor 0.031 to 0.05.  When 1.5 ≤ 0 < 3.5   (h/λ) X a is 0.025 to 0.05.  When 1.5 ≤ 0 < 3.5   (h/λ) X a is 0.025 to 0.05.  When 1.5 ≤ 0 < 3.5   (h/λ) X a is 0.025 to 0.05.  When 4.5 ≤ 0 < 5.5   (h/λ) X a is 0.025 to 0.05.  When 4.5 ≤ 0 < 5.5   (h/λ) X a is 0.025 to 0.05.  When 5.5 ≤ 0 < 6.5   (h/λ) X a is 0.025 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.025 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 15.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.  When 15.5 ≤ 0 < 10.5   (h/λ) X a is 0.015 to 0.05.				When $112.5 \le \theta \le 113.5$		
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		TABLE 2	40			
When 0 ≤ 0 < 1.5			_	When $113.5 \le \theta < 114.5$		
$\begin{array}{llllllllllllllllllllllllllllllllllll$	For [	$[0.15 \le H/\lambda \le 0.25]$	_	When $114.5 \le \theta \le 115.5$		
$\begin{array}{llllllllllllllllllllllllllllllllllll$	When $0 \le \theta \le 1.5$	$(h/\lambda)$ X a is 0.024 to 0.05.				
$\begin{array}{llllllllllllllllllllllllllllllllllll$	When $1.5 \le \theta \le 3.5$	$(h/\lambda)$ X a is 0.0235 to 0.05.				
$\begin{array}{llllllllllllllllllllllllllllllllllll$			45			
$\begin{array}{llllllllllllllllllllllllllllllllllll$		` /				
$\begin{array}{llllllllllllllllllllllllllllllllllll$		$(h/\lambda)$ X a is 0.022 to 0.05.				
$\begin{array}{llllllllllllllllllllllllllllllllllll$						
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	When $7.5 \le \theta < 8.5$	$(h/\lambda)$ X a is 0.021 to 0.05.			$(h/\lambda)$ X a is 0.0175 to 0.05.	
$\begin{array}{llllllllllllllllllllllllllllllllllll$		` /				
When $11.5 \le \theta < 12.5$			50	When $161.5 \le \theta \le 162.5$	$(h/\lambda)$ X a is 0.0195 to 0.05.	
When $11.5 \le \theta < 12.5$		· /		When $162.5 \le \theta \le 163.5$	$(h/\lambda)$ X a is 0.0205 to 0.05.	
When $12.5 \le \theta < 13.5$	When $11.5 \le \theta \le 12.5$	$(h/\lambda)$ X a is 0.0175 to 0.05.		When $163.5 \le \theta \le 164.5$	$(h/\lambda)$ X a is 0.021 to 0.05.	
When $13.5 \le \theta < 14.5$	When $12.5 \le \theta \le 13.5$	$(h/\lambda)$ X a is 0.0165 to 0.05.				
When $14.5 \le \theta < 15.5$ (h/k) X a is 0.013 to 0.05. When $15.5 \le \theta < 16.5$ (h/k) X a is 0.013 to 0.05. When $15.5 \le \theta < 16.5$ (h/k) X a is 0.011 to 0.05. When $16.5 \le \theta < 54.5$ (h/k) X a is 0.0125 to 0.05. When $16.5 \le \theta < 54.5$ (h/k) X a is 0.0125 to 0.05. When $16.5 \le \theta < 54.5$ (h/k) X a is 0.0125 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0235 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0235 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0235 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0235 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.024 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.024 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.024 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.025 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.025 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0235 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (h/k) X a is 0.0225 to 0.05. When $16.5 \le \theta < 16.5$ (	When $13.5 \le \theta \le 14.5$					
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$ \begin{array}{llllllllllllllllllllllllllllllllllll$			55		· /	
$\begin{array}{llllllllllllllllllllllllllllllllllll$						
When $56.5 \le \theta < 57.5$ (h/ $\lambda$ ) X a is 0.017 to 0.05. When $57.5 \le \theta < 58.5$ (h/ $\lambda$ ) X a is 0.0185 to 0.05. When $57.5 \le \theta < 58.5$ (h/ $\lambda$ ) X a is 0.0185 to 0.05. When $58.5 \le \theta < 59.5$ (h/ $\lambda$ ) X a is 0.0195 to 0.05. When $59.5 \le \theta < 60.5$ (h/ $\lambda$ ) X a is 0.0225 to 0.05. When $60.5 \le \theta < 61.5$ (h/ $\lambda$ ) X a is 0.0225 to 0.05. When $61.5 \le \theta < 62.5$ (h/ $\lambda$ ) X a is 0.0225 to 0.05. When $62.5 \le \theta < 63.5$ (h/ $\lambda$ ) X a is 0.023 to 0.05. When $63.5 \le \theta < 64.5$ (h/ $\lambda$ ) X a is 0.0235 to 0.05. When $63.5 \le \theta < 65.5$ (h/ $\lambda$ ) X a is 0.0235 to 0.05. When $65.5 \le \theta < 66.5$ (h/ $\lambda$ ) X a is 0.0245 to 0.05. When $65.5 \le \theta < 66.5$ (h/ $\lambda$ ) X a is 0.025 to 0.05.						
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$\begin{array}{llllllllllllllllllllllllllllllllllll$				When $179.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.024 to 0.05.	
$ \begin{array}{llllllllllllllllllllllllllllllllllll$						
$ \begin{array}{llllllllllllllllllllllllllllllllllll$			60			
					TADLE 2	
$ \begin{array}{llllllllllllllllllllllllllllllllllll$					TABLE 3	
When $64.5 \le \theta < 65.5$ (h/ $\lambda$ ) X a is 0.0245 to 0.05. When $65.5 \le \theta < 66.5$ (h/ $\lambda$ ) X a is 0.025 to 0.05. 65 When $0 \le \theta < 0.5$ (h/ $\lambda$ ) X a is 0.0245 to 0.05.		` '				
When $65.5 \le \theta < 66.5$ (h/ $\lambda$ ) X a is 0.025 to 0.05. (b/ $\lambda$ ) X a is 0.0245 to 0.05.				Fo	$r [0.25 \le H/\lambda < 0.35]$	
When one is the work of the wo			65	TTT 0 0 0 0 0	(1/2) 37 1 0 0045 : 0.05	
When $0.3 \le 0 < 0.3$ (n/A) X a is $0.0235$ to $0.05$ . When $0.5 \le 0 < 3.5$ (n/A) X a is $0.024$ to $0.05$ .			03			
	when $66.3 \le 6 < 6/.5$	(II/A) X a is 0.0255 to 0.05.		when $0.5 \le \theta \le 3.5$	(n/A) X a is 0.024 to 0.05.	

TABLE 3-continued

### TABLE 3-continued

For [	$0.25 \le H/\lambda \le 0.35]$		For [6	$0.25 \le H/\lambda < 0.35$
When $3.5 \le 0 < 4.5$ When $4.5 \le 0 < 6.5$ When $6.5 \le 0 < 7.5$ When $7.5 \le 0 < 8.5$	(h/ $\lambda$ ) X a is 0.0235 to 0.05. (h/ $\lambda$ ) X a is 0.023 to 0.05. (h/ $\lambda$ ) X a is 0.0225 to 0.05. (h/ $\lambda$ ) X a is 0.022 to 0.05.	5	When $161.5 \le \theta < 162.5$ When $162.5 \le \theta < 163.5$ When $163.5 \le \theta < 164.5$	(h/λ) X a is 0.02 to 0.05. (h/λ) X a is 0.0205 to 0.05. (h/λ) X a is 0.021 to 0.05.
When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 12.5$ When $12.5 \le \theta < 13.5$	(h/λ) X a is 0.0215 to 0.05. (h/λ) X a is 0.021 to 0.05. (h/λ) X a is 0.0205 to 0.05. (h/λ) X a is 0.0195 to 0.05. (h/λ) X a is 0.0195 to 0.05.	10	When $164.5 \le 0 < 165.5$ When $165.5 \le 0 < 166.5$ When $166.5 \le 0 < 168.5$ When $168.5 \le 0 < 169.5$ When $169.5 \le 0 < 171.5$	$(h/\lambda)$ X a is 0.022 to 0.05. $(h/\lambda)$ X a is 0.0225 to 0.05. $(h/\lambda)$ X a is 0.023 to 0.05. $(h/\lambda)$ X a is 0.023 to 0.05. $(h/\lambda)$ X a is 0.023 to 0.05.
When $13.5 \le \theta < 14.5$ When $14.5 \le \theta < 15.5$ When $15.5 \le \theta < 16.5$ When $16.5 \le \theta < 17.5$	$(h/\lambda)$ X a is 0.018 to 0.05. $(h/\lambda)$ X a is 0.017 to 0.05. $(h/\lambda)$ X a is 0.016 to 0.05. $(h/\lambda)$ X a is 0.015 to 0.05.	-	When $171.5 \le \theta < 180$	(h/λ) X a is 0.0245 to 0.05.
When $17.5 \le \theta \le 18.5$ When $18.5 \le \theta \le 19.5$ When $19.5 \le \theta \le 20.5$	(h/ $\lambda$ ) X a is 0.0135 to 0.05. (h/ $\lambda$ ) X a is 0.0115 to 0.05. (h/ $\lambda$ ) X a is 0.0095 to 0.05.	15 _		TABLE 4
When $20.5 \le \theta < 21.5$ When $21.5 \le \theta < 50.5$	$(h/\lambda)$ X a is 0.006 to 0.05. $(h/\lambda)$ X a is 0.005 to 0.05.	_	When $0 \le \theta \le 2.5$	$0.35 \le H/\lambda < 0.45$ ] (h/\lambda) X a is 0.0235 to 0.05.
When $50.5 \le \theta < 51.5$ When $51.5 \le \theta < 52.5$ When $52.5 \le \theta < 53.5$ When $53.5 \le \theta < 54.5$	$(h/\lambda)$ X a is 0.008 to 0.05. $(h/\lambda)$ X a is 0.0125 to 0.05. $(h/\lambda)$ X a is 0.015 to 0.05. $(h/\lambda)$ X a is 0.017 to 0.05.	20	When $2.5 \le \theta < 4.5$ When $4.5 \le \theta < 5.5$ When $5.5 \le \theta < 7.5$ When $5.5 \le \theta < 8.5$	(h/ $\lambda$ ) X a is 0.023 to 0.05. (h/ $\lambda$ ) X a is 0.0225 to 0.05. (h/ $\lambda$ ) X a is 0.0225 to 0.05. (h/ $\lambda$ ) X a is 0.022 to 0.05. (h/ $\lambda$ ) X a is 0.0215 to 0.05.
When $54.5 \le 0 < 55.5$ When $55.5 \le 0 < 56.5$ When $55.5 \le 0 < 56.5$ When $56.5 \le 0 < 57.5$ When $57.5 \le 0 < 58.5$	(h/λ) X a is 0.018 to 0.05. (h/λ) X a is 0.018 to 0.05. (h/λ) X a is 0.019 to 0.05. (h/λ) X a is 0.021 to 0.05.		When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$	$(h/\lambda)$ X a is 0.021 to 0.05. $(h/\lambda)$ X a is 0.0205 to 0.05. $(h/\lambda)$ X a is 0.02 to 0.05.
When $58.5 \le 0 \le 58.5$ When $58.5 \le 0 \le 59.5$ When $59.5 \le 0 \le 60.5$ When $60.5 \le 0 \le 61.5$ When $61.5 \le 0 \le 62.5$	(h/λ) X a is 0.021 to 0.05. (h/λ) X a is 0.022 to 0.05. (h/λ) X a is 0.023 to 0.05. (h/λ) X a is 0.023 to 0.05. (h/λ) X a is 0.0235 to 0.05.	25	When $11.5 \le \theta < 12.5$ When $12.5 \le \theta < 13.5$ When $13.5 \le \theta < 14.5$ When $14.5 \le \theta < 15.5$	$(h/\lambda)$ X a is 0.0195 to 0.05. $(h/\lambda)$ X a is 0.0185 to 0.05. $(h/\lambda)$ X a is 0.018 to 0.05. $(h/\lambda)$ X a is 0.017 to 0.05.
When $62.5 \le \theta < 63.5$ When $63.5 \le \theta < 64.5$ When $64.5 \le \theta < 65.5$	(h/λ) X a is 0.024 to 0.05. (h/λ) X a is 0.0245 to 0.05. (h/λ) X a is 0.025 to 0.05.	30	When $15.5 \le \theta < 16.5$ When $16.5 \le \theta < 17.5$ When $17.5 \le \theta < 18.5$ When $18.5 \le \theta < 19.5$	$(h/\lambda)$ X a is 0.016 to 0.05. $(h/\lambda)$ X a is 0.015 to 0.05. $(h/\lambda)$ X a is 0.0135 to 0.05. $(h/\lambda)$ X a is 0.0125 to 0.05.
When $65.5 \le \theta < 66.5$ When $66.5 \le \theta < 67.5$ When $67.5 \le \theta < 68.5$ When $68.5 \le \theta < 70.5$ When $70.5 \le \theta < 71.5$	(h/λ) X a is 0.0255 to 0.05. (h/λ) X a is 0.026 to 0.05. (h/λ) X a is 0.0265 to 0.05. (h/λ) X a is 0.027 to 0.05. (h/λ) X a is 0.027 to 0.05.		When $19.5 \le \theta < 20.5$ When $20.5 \le \theta < 21.5$ When $21.5 \le \theta < 22.5$ When $22.5 \le \theta < 49.5$ When $49.5 \le \theta < 50.5$	$(h/\lambda)$ X a is 0.0105 to 0.05. $(h/\lambda)$ X a is 0.008 to 0.05. $(h/\lambda)$ X a is 0.0055 to 0.05. $(h/\lambda)$ X a is 0.005 to 0.05. $(h/\lambda)$ X a is 0.0055 to 0.05.
When $71.5 \le \theta < 73.5$ When $73.5 \le \theta < 75.5$ When $75.5 \le \theta < 77.5$ When $75.5 \le \theta < 77.5$ When $77.5 \le \theta < 79.5$	(h/ $\lambda$ ) X a is 0.028 to 0.05. (h/ $\lambda$ ) X a is 0.028 to 0.05. (h/ $\lambda$ ) X a is 0.0285 to 0.05. (h/ $\lambda$ ) X a is 0.029 to 0.05. (h/ $\lambda$ ) X a is 0.0295 to 0.05.	35	When $50.5 \le 0 < 50.5$ When $50.5 \le 0 < 51.5$ When $51.5 \le 0 < 52.5$ When $52.5 \le 0 < 53.5$ When $53.5 \le 0 < 54.5$	$(h/\lambda)$ X a is 0.0035 to 0.05. $(h/\lambda)$ X a is 0.011 to 0.05. $(h/\lambda)$ X a is 0.0135 to 0.05. $(h/\lambda)$ X a is 0.0155 to 0.05. $(h/\lambda)$ X a is 0.017 to 0.05.
When $79.5 \le \theta < 82.5$ When $82.5 \le \theta < 85.5$ When $85.5 \le \theta < 89.5$ When $89.5 \le \theta < 102.5$	(h/ $\lambda$ ) X a is 0.3 to 0.05. (h/ $\lambda$ ) X a is 0.305 to 0.05. (h/ $\lambda$ ) X a is 0.305 to 0.05. (h/ $\lambda$ ) X a is 0.031 to 0.05. (h/ $\lambda$ ) X a is 0.0351 to 0.05.	40	When $54.5 \le \theta < 55.5$ When $55.5 \le \theta < 56.5$ When $56.5 \le \theta < 57.5$ When $57.5 \le \theta < 58.5$	$(h/\lambda)$ X a is 0.018 to 0.05. $(h/\lambda)$ X a is 0.019 to 0.05. $(h/\lambda)$ X a is 0.02 to 0.05. $(h/\lambda)$ X a is 0.0205 to 0.05.
When $102.5 \le \theta < 103.5$ When $103.5 \le \theta < 104.5$	(h/ $\lambda$ ) X a is 0.005 or 0.0315 to 0.05. (h/ $\lambda$ ) X a is 0.005 to 0.006 or 0.0315 to 0.05.		When $58.5 \le \theta < 59.5$ When $59.5 \le \theta < 60.5$ When $60.5 \le \theta < 61.5$ When $61.5 \le \theta < 62.5$	(h/λ) X a is 0.0215 to 0.05. (h/λ) X a is 0.022 to 0.05. (h/λ) X a is 0.022 to 0.05. (h/λ) X a is 0.0225 to 0.05. (h/λ) X a is 0.023 to 0.05.
When $104.5 \le \theta \le 105.5$	$(h/\lambda)$ X a is 0.005 to 0.007 or 0.0315 to 0.05.	45	When $62.5 \le \theta < 63.5$ When $63.5 \le \theta < 64.5$	$(h/\lambda) X a is 0.023 to 0.03.$ $(h/\lambda) X a is 0.0235 to 0.05.$ $(h/\lambda) X a is 0.024 to 0.05.$
When $105.5 \le \theta < 106.5$ When $106.5 \le \theta < 107.5$	(h/λ) X a is 0.005 to 0.008 or 0.031 to 0.05.		When $64.5 \le 0 < 65.5$ When $65.5 \le 0 < 67.5$	$(h/\lambda)$ X a is 0.0245 to 0.05. $(h/\lambda)$ X a is 0.025 to 0.05.
When $100.5 \le \theta < 107.5$	$(h/\lambda)$ X a is 0.005 to 0.009 or 0.031 to 0.05. $(h/\lambda)$ X a is 0.005 to 0.01 or 0.0305		When $67.5 \le \theta < 68.5$ When $68.5 \le \theta < 69.5$ When $69.5 \le \theta < 71.5$	$(h/\lambda)$ X a is 0.0255 to 0.05. $(h/\lambda)$ X a is 0.026 to 0.05. $(h/\lambda)$ X a is 0.0265 to 0.05.
When $108.5 \le \theta < 109.5$	to 0.05. (h/λ) X a is 0.005 to 0.0115 or 0.0305 to 0.05.	50	When $0.5 \le 0 < 71.5$ When $71.5 \le 0 < 72.5$ When $72.5 \le 0 < 74.5$ When $74.5 \le 0 < 76.5$	(h/λ) X a is 0.027 to 0.05. (h/λ) X a is 0.027 to 0.05. (h/λ) X a is 0.028 to 0.05.
When $109.5 \le \theta \le 110.5$	(h/λ) X a is 0.005 to 0.0125 or 0.03 to 0.05.		When $74.3 \le 0 < 70.5$ When $76.5 \le 0 < 79.5$ When $79.5 \le 0 < 82.5$	$(h/\lambda) X$ a is 0.028 to 0.05. $(h/\lambda) X$ a is 0.0285 to 0.05. $(h/\lambda) X$ a is 0.029 to 0.05.
When $110.5 \le \theta < 111.5$	$(h/\lambda)$ X a is 0.005 to 0.014 or 0.029 to 0.05.	55	When $82.5 \le \theta < 86.5$ When $86.5 \le \theta < 101.5$	(h/ $\lambda$ ) X a is 0.0295 to 0.05. (h/ $\lambda$ ) X a is 0.03 to 0.05.
When $111.5 \le \theta \le 112.5$ When $112.5 \le \theta \le 113.5$	(h/λ) X a is 0.005 to 0.016 or 0.028 to 0.05. (h/λ) X a is 0.005 to 0.0185 or		When $101.5 \le \theta < 103.5$ When $103.5 \le \theta < 104.5$ When $104.5 \le \theta < 105.5$	$(h/\lambda)$ X a is 0.0295 to 0.05. $(h/\lambda)$ X a is 0.005 or 0.0295 to 0.05 $(h/\lambda)$ X a is 0.005 to 0.006 or 0.029
When $113.5 \le \theta < 152.5$ When $152.5 \le \theta < 153.5$	(h/x) X a is 0.005 to 0.055 (h/x) X a is 0.005 to 0.05. (h/x) X a is 0.008 to 0.05.		When $104.5 \le \theta < 106.5$	to 0.05. (h/λ) X a is 0.005 to 0.007 or
When $152.5 \le \theta < 153.5$ When $153.5 \le \theta < 154.5$ When $154.5 \le \theta < 155.5$	$(h/\lambda) X$ a is 0.006 to 0.05. $(h/\lambda) X$ a is 0.0105 to 0.05. $(h/\lambda) X$ a is 0.012 to 0.05.	60	When $106.5 \le \theta \le 107.5$	0.0285 to 0.05. (h/λ) X a is 0.005 to 0.0085 or 0.0285 to 0.05.
When $155.5 \le \theta < 156.5$ When $156.5 \le \theta < 157.5$	(h/ $\lambda$ ) X a is 0.035 to 0.05. (h/ $\lambda$ ) X a is 0.015 to 0.05.		When $107.5 \le \theta \le 108.5$	$(h/\lambda)$ X a is 0.005 to 0.0095 or 0.028 to 0.05.
When $157.5 \le \theta < 158.5$ When $158.5 \le \theta < 159.5$	(h/ $\lambda$ ) X a is 0.0165 to 0.05. (h/ $\lambda$ ) X a is 0.0175 to 0.05.	65	When $108.5 \le \theta < 109.5$	(h/λ) X a is 0.005 to 0.011 or 0.027 to 0.05.
When $159.5 \le \theta < 160.5$ When $160.5 \le \theta < 161.5$	$(h/\lambda)$ X a is 0.018 to 0.05. $(h/\lambda)$ X a is 0.019 to 0.05.	65	When $109.5 \le \theta < 110.5$	$(h/\lambda)$ X a is 0.005 to 0.013 or 0.0265 to 0.05.

TABLE 4-continued

8

### TABLE 5-continued

For [	$0.35 \le H/\lambda < 0.45$		For [0.4	$45 \le H/\lambda \le 0.55$
When $110.5 \le \theta \le 111.5$	(h/λ) X a is 0.005 to 0.0145 or 0.0255 to 0.05.		When $96.5 \le \theta < 100.5$ When $100.5 \le \theta < 102.5$	$(h/\lambda)$ X a is 0.0285 to 0.045. $(h/\lambda)$ X a is 0.028 to 0.045.
When $111.5 \le \theta \le 112.5$	$(h/\lambda)$ X a is 0.005 to 0.019 or		When $102.5 \le \theta \le 103.5$	(h/λ) X a is 0.0275 to 0.045.
When $112.5 \le \theta \le 151.5$	0.0215 to $0.05$ . (h/ $\lambda$ ) X a is $0.005$ to $0.05$ .		When $103.5 \le \theta < 153.5$ When $153.5 \le \theta < 154.5$	$(h/\lambda)$ X a is 0.05 to 0.045. $(h/\lambda)$ X a is 0.075 to 0.045.
When $151.5 \le \theta < 152.5$	$(h/\lambda)$ X a is 0.0055 to 0.05.		When $154.5 \le \theta < 155.5$	$(h/\lambda)$ X a is 0.095 to 0.045.
When $152.5 \le \theta \le 153.5$	$(h/\lambda)$ X a is 0.0075 to 0.05.		When $155.5 \le \theta \le 156.5$	$(h/\lambda)$ X a is 0.011 to 0.045.
When $153.5 \le \theta \le 154.5$	$(h/\lambda)$ X a is 0.01 to 0.05.	10	When $156.5 \le \theta < 157.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.
When $154.5 \le \theta \le 155.5$	$(h/\lambda)$ X a is 0.0115 to 0.05.		When $157.5 \le \theta \le 158.5$	$(h/\lambda)$ X a is 0.0135 to 0.045.
When $155.5 \le \theta \le 156.5$	$(h/\lambda)$ X a is 0.013 to 0.05.		When $158.5 \le \theta \le 159.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.
When $156.5 \le \theta \le 157.5$	$(h/\lambda)$ X a is 0.014 to 0.05.		When $159.5 \le \theta \le 160.5$	$(h/\lambda)$ X a is 0.016 to 0.045.
When $157.5 \le \theta \le 158.5$	$(h/\lambda)$ X a is 0.0155 to 0.05.		When $160.5 \le \theta \le 161.5$	$(h/\lambda)$ X a is 0.0165 to 0.045.
When $158.5 \le \theta < 159.5$	$(h/\lambda)$ X a is 0.0165 to 0.05.		When $161.5 \le \theta \le 162.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.
When $159.5 \le \theta \le 160.5$	$(h/\lambda)$ X a is 0.017 to 0.05.	15	When $162.5 \le \theta \le 163.5$	$(h/\lambda)$ X a is 0.018 to 0.045.
When $160.5 \le \theta \le 161.5$	$(h/\lambda)$ X a is 0.018 to 0.05.		When $163.5 \le \theta \le 164.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
When $161.5 \le \theta \le 162.5$	$(h/\lambda)$ X a is 0.018 to 0.05.		When $164.5 \le \theta \le 165.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.
When $162.5 \le \theta \le 163.5$	$(h/\lambda)$ X a is 0.0195 to 0.05.		When $165.5 \le \theta \le 166.5$	$(h/\lambda)$ X a is 0.02 to 0.045.
When $163.5 \le \theta \le 164.5$	$(h/\lambda)$ X a is 0.02 to 0.05.		When $166.5 \le \theta \le 167.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.
When $164.5 \le \theta \le 165.5$	$(h/\lambda)$ X a is 0.021 to 0.05.		When $167.5 \le \theta \le 168.5$	$(h/\lambda)$ X a is 0.021 to 0.045.
When $165.5 \le \theta \le 166.5$	$(h/\lambda)$ X a is 0.0215 to 0.05.	20	When $168.5 \le \theta \le 170.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.
When $166.5 \le \theta \le 168.5$	$(h/\lambda)$ X a is 0.022 to 0.05.		When $170.5 \le \theta \le 172.5$	$(h/\lambda)$ X a is 0.022 to 0.045.
When $168.5 \le \theta \le 169.5$	$(h/\lambda)$ X a is 0.0225 to 0.05.		When $172.5 \le \theta \le 175.5$	$(h/\lambda)$ X a is 0.0225 to 0.045.
When $169.5 \le \theta \le 171.5$	$(h/\lambda)$ X a is 0.023 to 0.05.		When $175.5 \le \theta \le 179.5$	$(h/\lambda)$ X a is 0.023 to 0.045.
When $171.5 \le \theta \le 175.5$	$(h/\lambda)$ X a is 0.0235 to 0.05.		When $179.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.0225 to 0.045.
When $175.5 \le \theta \le 178.5$	$(h/\lambda)$ X a is 0.024 to 0.05.	_		, ,
When $178.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.0235 to 0.05.	25		

### TABLE 6

TABLE 5	For $[0.55 \le H/\lambda < 0.65]$

For [0.	45 ≤ H/λ < 0.55]	30	When $0 \le \theta \le 0.5$	$(h/\lambda) X$ a is 0.022 to 0.045.
			When $0.5 \le \theta \le 3.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.
When $0 \le \theta \le 2.5$	$(h/\lambda)$ X a is 0.0225 to 0.045.		When $3.5 \le \theta < 5.5$	$(h/\lambda)$ X a is 0.021 to 0.045.
When $2.5 \le \theta \le 4.5$	$(h/\lambda)$ X a is 0.022 to 0.045.		When $5.5 \le \theta \le 6.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.
When $4.5 \le \theta \le 6.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.		When $6.5 \le \theta < 7.5$	$(h/\lambda)$ X a is 0.02 to 0.045.
When $6.5 \le \theta < 7.5$	$(h/\lambda)$ X a is 0.021 to 0.045.		When $7.5 \le \theta < 9.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.
When $7.5 \le \theta < 8.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.	35	When $9.5 \le \theta \le 10.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
When $8.5 \le \theta < 9.5$	$(h/\lambda)$ X a is 0.02 to 0.045.	33	When $10.5 \le \theta \le 11.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.
When $9.5 \le \theta < 10.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.		When $11.5 \le \theta < 12.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.
When $10.5 \le \theta < 11.5$	$(h/\lambda)$ X a is 0.019 to 0.045.		When $12.5 \le \theta < 13.5$	$(h/\lambda)$ X a is 0.017 to 0.045.
When $11.5 \le \theta < 12.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.		When $13.5 \le \theta < 14.5$	$(h/\lambda)$ X a is 0.0165 to 0.045.
When $12.5 \le \theta < 13.5$	$(h/\lambda)$ X a is 0.018 to 0.045.		When $14.5 \le \theta < 15.5$	$(h/\lambda)$ X a is 0.0155 to 0.045.
When $13.5 \le \theta \le 14.5$	$(h/\lambda)$ X a is 0.017 to 0.045.	• •	When $15.5 \le \theta \le 16.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.
When $14.5 \le \theta \le 15.5$	(h/λ) X a is 0.0165 to 0.045.	40	When $16.5 \le \theta \le 17.5$	$(h/\lambda)$ X a is 0.0135 to 0.045.
When $15.5 \le \theta \le 16.5$	(h/λ) X a is 0.0155 to 0.045.		When $17.5 \le \theta \le 18.5$	$(h/\lambda)$ X a is 0.012 to 0.045.
When $16.5 \le \theta < 17.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.		When $18.5 \le \theta < 19.5$	$(h/\lambda)$ X a is 0.011 to 0.045.
When $17.5 \le \theta \le 18.5$	$(h/\lambda)$ X a is 0.013 to 0.045.		When $19.5 \le \theta \le 20.5$	$(h/\lambda)$ X a is 0.009 to 0.045.
When $18.5 \le \theta < 19.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.		When $20.5 \le \theta < 21.5$	$(h/\lambda)$ X a is 0.0065 to 0.045.
When $19.5 \le \theta < 20.5$	$(h/\lambda)$ X a is 0.01 to 0.045.		When $21.5 \le \theta < 50.5$	$(h/\lambda)$ X a is 0.005 to 0.045.
When $20.5 \le \theta \le 21.5$	$(h/\lambda)$ X a is 0.008 to 0.045.	45	When $50.5 \le \theta < 51.5$	$(h/\lambda)$ X a is 0.0085 to 0.045.
When $21.5 \le \theta < 50.5$	$(h/\lambda)$ X a is 0.005 to 0.045.		When $51.5 \le \theta < 52.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.
When $50.5 \le \theta < 51.5$	$(h/\lambda)$ X a is 0.003 to 0.045.		When $52.5 \le 0 < 52.5$ When $52.5 \le 0 < 53.5$	$(h/\lambda) X a is 0.0113 to 0.043.$ $(h/\lambda) X a is 0.0135 to 0.045.$
When $51.5 \le \theta < 52.5$	$(h/\lambda)$ X a is 0.0103 to 0.045.		When $53.5 \le 0 < 53.5$ When $53.5 \le 0 < 54.5$	$(h/\lambda) X a is 0.0155 to 0.045.$
When $52.5 \le \theta < 52.5$ When $52.5 \le \theta < 53.5$	$(h/\lambda)$ X a is 0.013 to 0.045.		When $54.5 \le 0 < 54.5$ When $54.5 \le 0 < 55.5$	$(h/\lambda) X a is 0.0155 to 0.045.$
When $53.5 \le \theta < 54.5$	$(h/\lambda)$ X a is 0.013 to 0.045.		When $55.5 \le 0 < 55.5$	$(h/\lambda) X a is 0.0103 to 0.045.$
When $54.5 \le \theta < 55.5$	$(h/\lambda)$ X a is 0.010 to 0.045. $(h/\lambda)$ X a is 0.0175 to 0.045.	50	When $56.5 \le 0 < 56.5$ When $56.5 \le 0 < 57.5$	$(h/\lambda) X$ a is 0.0173 to 0.043. $(h/\lambda) X$ a is 0.0185 to 0.045.
When $54.5 \le 0 < 55.5$ When $55.5 \le \theta < 56.5$	$(h/\lambda)$ X a is 0.0173 to 0.043. $(h/\lambda)$ X a is 0.0185 to 0.045.	30		$(h/\lambda) X$ a is 0.0183 to 0.045. $(h/\lambda) X$ a is 0.019 to 0.045.
When $56.5 \le \theta < 50.5$ When $56.5 \le \theta < 57.5$	$(h/\lambda)$ X a is 0.0183 to 0.043. $(h/\lambda)$ X a is 0.019 to 0.045.		When $57.5 _{[M1]} \le \theta \le 58.5$ When $58.5 \le \theta \le 59.5$	$(h/\lambda)$ X a is 0.019 to 0.045. $(h/\lambda)$ X a is 0.02 to 0.045.
	. ,			. ,
When $57.5 \le \theta \le 58.5$	$(h/\lambda)$ X a is 0.02 to 0.045.		When $59.5 \le \theta < 60.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.
When $58.5 \le \theta \le 59.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.		When $60.5 \le \theta < 61.5$	$(h/\lambda)$ X a is 0.021 to 0.045.
When $59.5 \le \theta \le 60.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.		When $61.5 \le \theta < 62.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.
When $60.5 \le \theta \le 61.5$	$(h/\lambda)$ X a is 0.022 to 0.045.	55	When $62.5 \le \theta < 63.5$	$(h/\lambda)$ X a is 0.022 to 0.045.
When $61.5 \le \theta \le 62.5$	$(h/\lambda)$ X a is 0.0225 to 0.045.		When $63.5 \le \theta < 64.5$	$(h/\lambda)$ X a is 0.0225 to 0.045.
When $62.5 \le \theta < 63.5$	$(h/\lambda)$ X a is 0.023 to 0.045.		When $64.5 \le \theta < 65.5$	$(h/\lambda)$ X a is 0.023 to 0.045.
When $63.5 \le \theta < 65.5$	$(h/\lambda)$ X a is 0.0235 to 0.045.		When $65.5 \le \theta < 67.5$	$(h/\lambda)$ X a is 0.0235 to 0.045.
When $65.5 \le \theta < 66.5$	$(h/\lambda)$ X a is 0.024 to 0.045.		When $67.5 \le \theta < 68.5$	$(h/\lambda)$ X a is 0.024 to 0.045.
When $66.5 \le \theta < 67.5$	$(h/\lambda)$ X a is 0.0245 to 0.045.		When $68.5 \le \theta < 70.5$	$(h/\lambda)$ X a is 0.0245 to 0.045.
When $67.5 \le \theta < 69.5$	$(h/\lambda)$ X a is 0.025 to 0.045.	60	When $70.5 \le \theta < 72.5$	$(h/\lambda)$ X a is 0.025 to 0.045.
When $69.5 \le \theta < 70.5$	$(h/\lambda)$ X a is 0.0255 to 0.045.	00	When $72.5 \le \theta < 73.5$	$(h/\lambda)$ X a is 0.0255 to 0.045.
When $70.5 \le \theta < 72.5$	$(h/\lambda)$ X a is 0.026 to 0.045.		When $73.5 \le \theta < 75.5$	$(h/\lambda)$ X a is 0.026 to 0.045.
When $72.5 \le \theta < 74.5$	$(h/\lambda)$ X a is 0.0265 to 0.045.		When $75.5 \le \theta < 78.5$	$(h/\lambda)$ X a is 0.0265 to 0.045.
When $74.5 \le \theta < 76.5$	$(h/\lambda)$ X a is 0.027 to 0.045.		When $78.5 \le \theta \le 81.5$	$(h/\lambda)$ X a is 0.027 to 0.045.
When $76.5 \le \theta < 79.5$	$(h/\lambda)$ X a is 0.0275 to 0.045.		When $81.5 \le \theta \le 85.5$	$(h/\lambda)$ X a is 0.0275 to 0.045.
When $79.5 \le \theta \le 82.5$	$(h/\lambda)$ X a is 0.028 to 0.045.		When $85.5 \le \theta < 95.5$	$(h/\lambda)$ X a is 0.028 to 0.045.
When $82.5 \le \theta \le 87.5$	$(h/\lambda)$ X a is 0.0285 to 0.045.	65	When $95.5 \le \theta < 98.5$	$(h/\lambda)$ X a is 0.0275 to 0.045.
When $87.5 \le \theta \le 96.5$	$(h/\lambda)$ X a is 0.029 to 0.045.		When $98.5 \le \theta \le 101.5$	$(h/\lambda)$ X a is 0.027 to 0.045.

TABLE 6-continued

# 10 TABLE 7-continued

IADLI	E 0-continued		IADLI	z /-continued
For [0.5	55 ≤ H/λ < 0.65]		For [0.6	$55 \le H/\lambda < 0.75$
NII 101.5 0 - 102.5	(I (A ) No. 1 (A ) 0.02(5)		WH 150.5 0 4160.5	(1.0) 37 1 0.0115 ( 0.045
When $101.5 \le \theta < 102.5$	$(h/\lambda)$ X a is 0.0265 to 0.045.	5	When $159.5 \le \theta < 160.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.
When $102.5 \le \theta < 103.5$	$(h/\lambda)$ X a is 0.026 to 0.045.	3	When $160.5 \le \theta < 161.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.
When $103.5 \le \theta < 154.5$	$(h/\lambda)$ X a is 0.005 to 0.045.		When $161.5 \le \theta < 162.5$	$(h/\lambda)$ X a is 0.014 to 0.045.
When $154.5 \le \theta < 155.5$	$(h/\lambda)$ X a is 0.0055 to 0.045.		When $162.5 \le \theta \le 163.5$	$(h/\lambda)$ X a is 0.015 to 0.045.
When $155.5 \le \theta < 156.5$	$(h/\lambda)$ X a is 0.008 to 0.045.		When $163.5 \le \theta \le 164.5$	$(h/\lambda)$ X a is 0.016 to 0.045.
When $156.5 \le \theta < 157.5$	$(h/\lambda)$ X a is 0.01 to 0.045.		When $164.5 \le \theta \le 165.5$	$(h/\lambda)$ X a is 0.0165 to 0.045.
When $157.5 \le \theta \le 158.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.		When $165.5 \le \theta \le 166.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.
When $158.5 \le \theta \le 159.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.	10	When $166.5 \le \theta < 167.5$	$(h/\lambda)$ X a is 0.018 to 0.045.
When $159.5 \le \theta < 160.5$	$(h/\lambda)$ X a is 0.014 to 0.045.			
When $160.5 \le \theta \le 161.5$	$(h/\lambda)$ X a is 0.015 to 0.045.		When $167.5 \le \theta < 168.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.
When $161.5 \le \theta \le 162.5$	$(h/\lambda)$ X a is 0.016 to 0.045.		When $168.5 \le \theta < 169.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
When $162.5 \le \theta < 163.5$	$(h/\lambda)$ X a is 0.0165 to 0.045.		When $169.5 \le \theta < 170.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.
When $163.5 \le \theta < 164.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.		When $170.5 \le \theta \le 172.5$	$(h/\lambda)$ X a is 0.02 to 0.045.
When $164.5 \le 0 < 164.5$ When $164.5 \le 0 < 165.5$	· · · · · ·		When $172.5 \le \theta \le 175.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.
	$(h/\lambda)$ X a is 0.018 to 0.045.	15	When $175.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.021 to 0.045.
When $165.5 \le \theta < 166.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.	_		
When $166.5 \le \theta < 168.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.			
When $168.5 \le \theta < 169.5$	$(h/\lambda)$ X a is 0.02 to 0.045.			
When $169.5 \le \theta \le 170.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.		Т	ADLEO
When $171.5 \le \theta \le 172.5$	$(h/\lambda)$ X a is 0.021 to 0.045.		1.	ABLE 8
When $172.5 \le \theta < 175.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.	20		
When $175.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.022 to 0.045.	_	For [0.7	'5 ≤ H/λ < 0.85]
			When $0 \le \theta \le 3.5$	(h/λ) X a is 0.02 to 0.045.
			When $3.5 \le \theta < 5.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.
			When $5.5 \le 0 < 6.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
т	ABLE 7		When $6.5 \le \theta < 8.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
1.	ADLE /	25	When $8.5 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$	$(h/\lambda)$ X a is 0.0183 to 0.043. $(h/\lambda)$ X a is 0.018 to 0.045.
T 50.0	55 - 110 - 0.751		When $9.5 \le 0 < 9.5$ When $9.5 \le \theta < 10.5$	$(h/\lambda)$ X a is 0.018 to 0.045. $(h/\lambda)$ X a is 0.0175 to 0.045.
For [0.6	$65 \le H/\lambda < 0.75$		When $10.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$	$(h/\lambda)$ X a is 0.0173 to 0.043. $(h/\lambda)$ X a is 0.017 to 0.045.
When 0 = 0 < 1.5	(h/λ) X a is 0.021 to 0.045.			
When $0 \le \theta \le 1.5$			When $11.5 \le \theta < 12.5$	$(h/\lambda)$ X a is 0.016 to 0.045.
When $1.5 \le \theta < 4.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.		When $12.5 \le \theta < 13.5$	$(h/\lambda)$ X a is 0.0155 to 0.045.
When $4.5 \le \theta < 5.5$	$(h/\lambda)$ X a is 0.02 to 0.045.		When $13.5 \le \theta < 14.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.
When $5.5 \le \theta < 7.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.	30	When $14.5 \le \theta < 15.5$	$(h/\lambda)$ X a is 0.014 to 0.045.
When $7.5 \le \theta \le 8.5$	$(h/\lambda)$ X a is 0.019 to 0.045.		When $15.5 \le \theta < 16.5$	$(h/\lambda)$ X a is 0.013 to 0.045.
When $8.5 \le \theta < 9.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.		When $16.5 \le \theta < 17.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.
When $9.5 \le \theta < 10.5$	$(h/\lambda)$ X a is 0.018 to 0.045.		When $17.5 \le \theta < 18.5$	$(h/\lambda)$ X a is 0.0105 to 0.045.
When $10.5 \le \theta < 11.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.		When $18.5 \le \theta < 19.5$	$(h/\lambda)$ X a is 0.0085 to 0.045.
When $11.5 \le \theta \le 12.5$	$(h/\lambda)$ X a is 0.017 to 0.045.		When $19.5 \le \theta \le 20.5$	$(h/\lambda)$ X a is 0.0065 to 0.045.
When $12.5 \le \theta \le 13.5$	$(h/\lambda)$ X a is 0.016 to 0.045.	35	When $20.5 \le \theta \le 51.5$	$(h/\lambda)$ X a is 0.005 to 0.045.
When $13.5 \le \theta \le 14.5$	$(h/\lambda)$ X a is 0.0155 to 0.045.		When $51.5 \le \theta \le 52.5$	$(h/\lambda)$ X a is 0.0085 to 0.045.
When $14.5 \le \theta < 15.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.		When $52.5 \le \theta < 53.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.
When $15.5 \le \theta \le 16.5$	$(h/\lambda)$ X a is 0.0135 to 0.045.		When $53.5 \le \theta < 54.5$	$(h/\lambda)$ X a is 0.013 to 0.045.
When $16.5 \le \theta < 17.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.		When $54.5 \le \theta < 55.5$	$(h/\lambda)$ X a is 0.0145 to 0.045.
When $17.5 \le \theta \le 18.5$	$(h/\lambda)$ X a is 0.0115 to 0.045.		When $55.5 \le \theta < 56.5$	$(h/\lambda)$ X a is 0.016 to 0.045.
When $18.5 \le \theta < 19.5$	$(h/\lambda)$ X a is 0.0095 to 0.045.		When $56.5 \le \theta < 57.5$	$(h/\lambda)$ X a is 0.017 to 0.045.
When $19.5 \le \theta \le 20.5$	$(h/\lambda)$ X a is 0.0075 to 0.045.	40	When $57.5 \le \theta \le 58.5$	$(h/\lambda)$ X a is 0.0175 to 0.045.
When $20.5 \le \theta \le 21.5$	(h/λ) X a is 0.0055 to 0.045.		When $58.5 \le \theta < 59.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.
When $21.5 \le \theta < 50.5$	$(h/\lambda)$ X a is 0.005 to 0.045.		When $59.5 \le \theta < 60.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
When $50.5 \le \theta < 51.5$	$(h/\lambda)$ X a is 0.0065 to 0.045.		When $60.5 \le \theta \le 61.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.
When $51.5 \le \theta < 52.5$	$(h/\lambda)$ X a is 0.0105 to 0.045.		When $61.5 \le \theta < 62.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.
When $52.5 \le \theta < 53.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.		When $62.5 \le \theta < 63.5$	$(h/\lambda)$ X a is 0.0203 to 0.045.
When $53.5 \le \theta < 54.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.	45	When $63.5 \le \theta < 65.5$	$(h/\lambda)$ X a is 0.021 to 0.045.
When $54.5 \le 0 < 54.5$ When $54.5 \le 0 < 55.5$	$(h/\lambda)$ X a is 0.014 to 0.045.		When $65.5 \le 0 < 66.5$	$(h/\lambda)$ X a is 0.0213 to 0.045.
When $54.5 \le \theta < 55.5$ When $55.5 \le \theta < 56.5$	$(h/\lambda) X a$ is 0.0133 to 0.043. $(h/\lambda) X a$ is 0.0165 to 0.045.		When $66.5 \le \theta < 67.5$	$(h/\lambda)$ X a is 0.022 to 0.043. $(h/\lambda)$ X a is 0.0225 to 0.045.
When $56.5 \le \theta < 57.5$	$(h/\lambda) X a$ is 0.0103 to 0.043. $(h/\lambda) X a$ is 0.0175 to 0.045.		When $67.5 \le \theta < 68.5$	$(h/\lambda)$ X a is 0.0223 to 0.043. $(h/\lambda)$ X a is 0.023 to 0.045.
	$(h/\lambda)$ X a is 0.0173 to 0.043. $(h/\lambda)$ X a is 0.0185 to 0.045.		When $68.5 \le \theta < 70.5$	. ,
When $57.5 \le \theta \le 58.5$	. ,			$(h/\lambda)$ X a is 0.0235 to 0.045.
When $58.5 \le \theta < 59.5$	$(h/\lambda)$ X a is 0.019 to 0.045.		When $70.5 \le \theta < 72.5$	$(h/\lambda)$ X a is 0.024 to 0.045.
When $60.5 \le \theta \le 60.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.	50	When $72.5 \le \theta < 74.5$	$(h/\lambda)$ X a is 0.0245 to 0.045.
When $60.5 \le \theta < 61.5$	$(h/\lambda)$ X a is 0.0205 to 0.045.		When $74.5 \le \theta < 76.5$	$(h/\lambda)$ X a is 0.025 to 0.045.
When $61.5 \le \theta < 62.5$	$(h/\lambda)$ X a is 0.021 to 0.045.		When $76.5 \le \theta < 79.5$	$(h/\lambda)$ X a is 0.0255 to 0.045.
When $62.5 \le \theta < 63.5$	$(h/\lambda)$ X a is 0.0215 to 0.045.		When $79.5 \le \theta < 83.5$	$(h/\lambda)$ X a is 0.026 to 0.045.
When $63.5 \le \theta < 64.5$	$(h/\lambda)$ X a is 0.022 to 0.045.		When $83.5 \le \theta < 96.5$	$(h/\lambda)$ X a is 0.0265 to 0.045.
When $64.5 \le \theta < 66.5$	$(h/\lambda)$ X a is 0.0225 to 0.045.		When $96.5 \le \theta < 98.5$	$(h/\lambda)$ X a is 0.026 to 0.045.
When $66.5 \le \theta < 67.5$	$(h/\lambda)$ X a is 0.023 to 0.045.	55	When $98.5 \le \theta < 99.5$	$(h/\lambda)$ X a is 0.025 to 0.045.
When $67.5 \le \theta < 68.5$	$(h/\lambda)$ X a is 0.0235 to 0.045.		When $99.5 \le \theta < 100.5$	$(h/\lambda)$ X a is 0.0245 to 0.045.
When $68.5 \le \theta < 70.5$	$(h/\lambda)$ X a is 0.024 to 0.045.		When $100.5 \le \theta \le 159.5$	$(h/\lambda)$ X a is 0.005 to 0.045.
When $70.5 \le \theta < 72.5$	$(h/\lambda)$ X a is 0.0245 to 0.045.		When $159.5 \le \theta \le 160.5$	$(h/\lambda)$ X a is 0.0055 to 0.045.
When $72.5 \le \theta < 74.5$	$(h/\lambda)$ X a is 0.025 to 0.045.		When $160.5 \le \theta \le 161.5$	$(h/\lambda)$ X a is 0.009 to 0.045.
When $74.5 \le \theta < 76.5$	$(h/\lambda)$ X a is 0.0255 to 0.045.		When $161.5 \le \theta \le 162.5$	$(h/\lambda)$ X a is 0.011 to 0.045.
When $76.5 \le \theta < 79.5$	$(h/\lambda)$ X a is 0.026 to 0.045.	60	When $162.5 \le \theta \le 163.5$	$(h/\lambda)$ X a is 0.0125 to 0.045.
When $79.5 \le \theta \le 82.5$	$(h/\lambda)$ X a is 0.0265 to 0.045.	60	When $163.5 \le \theta \le 164.5$	$(h/\lambda)$ X a is 0.014 to 0.045.
When $82.5 \le \theta < 95.5$	$(h/\lambda)$ X a is 0.027 to 0.045.		When $164.5 \le \theta \le 165.5$	$(h/\lambda)$ X a is 0.015 to 0.045.
When $95.5 \le \theta < 98.5$	(h/λ) X a is 0.0265 to 0.045.		When $165.5 \le \theta \le 166.5$	$(h/\lambda)$ X a is 0.016 to 0.045.
When $98.5 \le \theta < 100.5$	$(h/\lambda)$ X a is 0.026 to 0.045.		When $166.5 \le \theta < 167.5$	$(h/\lambda)$ X a is 0.0165 to 0.045.
When $100.5 \le \theta \le 101.5$	$(h/\lambda)$ X a is 0.0255 to 0.045.		When $167.5 \le \theta \le 168.5$	$(h/\lambda)$ X a is 0.017 to 0.045.
When $101.5 \le \theta < 157.5$	$(h/\lambda)$ X a is 0.005 to 0.045.		When $168.5 \le \theta < 169.5$	$(h/\lambda)$ X a is 0.018 to 0.045.
When $157.5 \le \theta < 158.5$	$(h/\lambda)$ X a is 0.0075 to 0.045.	65	When $169.5 \le \theta < 171.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.
When $158.5 \le \theta < 159.5$	$(h/\lambda)$ X a is 0.01 to 0.045.		When $171.5 \le \theta < 172.5$	$(h/\lambda)$ X a is 0.019 to 0.045.
nen 150.5 = 0 × 155.5	(11.14) 22 4 10 0.01 10 0.070.		on 1/1.0 = 0 \ 1/2.0	(1177) 22 4 15 0.017 10 0.017.

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TABLE 8-continued

### **12** TABLE 10-continued

When $172.5 \le \theta \le 174.5$	$(h/\lambda)$ X a is 0.0195 to 0.045.	
When $174.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.02 to 0.045.	

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	A	151	ıΡ.	9	

	BEE 7
For [0.85	$5 \le H/\lambda < 0.95$
When $0 \le \theta \le 2.5$	$(h/\lambda) \times a \text{ is } 0.0195 \text{ to } 0.045.$
When $2.5 \le \theta \le 4.5$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.045.$
When $4.5 \le \theta < 6.5$	$(h/\lambda) \times a \text{ is } 0.0185 \text{ to } 0.045.$
When $6.5 \le \theta < 7.5$	$(h/\lambda) \times a \text{ is } 0.018 \text{ to } 0.045.$
When $7.5 \le \theta < 9.5$	$(h/\lambda) \times a \text{ is } 0.0175 \text{ to } 0.045.$
When $9.5 \le \theta \le 10.5$	$(h/\lambda) \times a \text{ is } 0.017 \text{ to } 0.045.$
When $10.5 \le \theta \le 11.5$	$(h/\lambda) \times a \text{ is } 0.016 \text{ to } 0.045.$
When $11.5 \le \theta \le 12.5$	$(h/\lambda) \times a \text{ is } 0.0155 \text{ to } 0.045.$
When $12.5 \le \theta < 13.5$	$(h/\lambda) \times a \text{ is } 0.015 \text{ to } 0.045.$
When $13.5 \le \theta \le 14.5$	$(h/\lambda) \times a \text{ is } 0.014 \text{ to } 0.045.$
When $14.5 \le \theta \le 15.5$	$(h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.045.$
When $15.5 \le \theta \le 16.5$	$(h/\lambda) \times a \text{ is } 0.012 \text{ to } 0.045.$
When $16.5 \le \theta \le 17.5$	$(h/\lambda) \times a \text{ is } 0.011 \text{ to } 0.045.$
When $17.5 \le \theta \le 18.5$	$(h/\lambda) \times a \text{ is } 0.009 \text{ to } 0.045.$
When $18.5 \le \theta < 19.5$	$(h/\lambda) \times a \text{ is } 0.007 \text{ to } 0.045.$
When $19.5 \le \theta \le 51.5$	$(h/\lambda) \times a \text{ is } 0.007 \text{ to } 0.045.$
When $51.5 \le \theta \le 52.5$	$(h/\lambda) \times a \text{ is } 0.0065 \text{ to } 0.045.$
When $52.5 \le \theta \le 53.5$	$(h/\lambda) \times a \text{ is } 0.0105 \text{ to } 0.045.$
When $53.5 \le \theta < 54.5$	$(h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.045.$
When $54.5 \le \theta < 55.5$	$(h/\lambda) \times a \text{ is } 0.014 \text{ to } 0.045.$
When $55.5 \le \theta < 56.5$	$(h/\lambda) \times a \text{ is } 0.015 \text{ to } 0.045.$
When $56.5 \le \theta < 57.5$	$(h/\lambda) \times a \text{ is } 0.016 \text{ to } 0.045.$
When $57.5 \le \theta < 58.5$	$(h/\lambda) \times a \text{ is } 0.017 \text{ to } 0.045.$
When $58.5 \le \theta < 59.5$	$(h/\lambda) \times a \text{ is } 0.018 \text{ to } 0.045.$
When $59.5 \le \theta < 60.5$	$(h/\lambda) \times a \text{ is } 0.0185 \text{ to } 0.045.$
When $60.5 \le \theta \le 61.5$ When $61.5 \le \theta \le 62.5$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.045.$ $(h/\lambda) \times a \text{ is } 0.02 \text{ to } 0.045.$
When $61.5 \le 0 < 62.5$ When $62.5 \le 0 < 63.5$	$(h/\lambda) \times a$ is 0.02 to 0.043. $(h/\lambda) \times a$ is 0.0205 to 0.045.
When $63.5 \le 0 < 63.5$ When $63.5 \le 0 < 64.5$	$(h/\lambda) \times a$ is 0.0203 to 0.043. $(h/\lambda) \times a$ is 0.021 to 0.045.
When $64.5 \le \theta < 65.5$	$(h/\lambda) \times a$ is 0.021 to 0.045. $(h/\lambda) \times a$ is 0.0215 to 0.045.
When $65.5 \le \theta < 66.5$	$(h/\lambda) \times a$ is 0.022 to 0.045.
When $66.5 \le \theta < 68.5$	$(h/\lambda) \times a \text{ is } 0.0225 \text{ to } 0.045.$
When $68.5 \le \theta \le 70.5$	$(h/\lambda) \times a \text{ is } 0.023 \text{ to } 0.045.$
When $70.5 \le \theta < 72.5$	$(h/\lambda) \times a \text{ is } 0.0235 \text{ to } 0.045.$
When $72.5 \le \theta < 74.5$	$(h/\lambda) \times a \text{ is } 0.024 \text{ to } 0.045.$
When $74.5 \le \theta < 76.5$	$(h/\lambda) \times a \text{ is } 0.0245 \text{ to } 0.045.$
When $76.5 \le \theta < 79.5$	$(h/\lambda) \times a \text{ is } 0.025 \text{ to } 0.045.$
When $79.5 \le \theta < 82.5$	$(h/\lambda) \times a \text{ is } 0.0255 \text{ to } 0.045.$
When $82.5 \le \theta \le 92.5$	$(h/\lambda) \times a \text{ is } 0.026 \text{ to } 0.045.$
When $92.5 \le \theta < 95.5$	$(h/\lambda) \times a \text{ is } 0.0255 \text{ to } 0.045.$
When $95.5 \le \theta < 97.5$	$(h/\lambda) \times a \text{ is } 0.025 \text{ to } 0.045.$
When $97.5 \le \theta < 98.5$	$(h/\lambda) \times a \text{ is } 0.0245 \text{ to } 0.045.$
When $98.5 \le \theta < 163.5$	$(h/\lambda) \times a \text{ is } 0.05 \text{ to } 0.045.$
When $163.5 \le \theta < 164.5$	$(h/\lambda) \times a \text{ is } 0.0105 \text{ to } 0.045.$
When $164.5 \le \theta < 165.5$	$(h/\lambda) \times a \text{ is } 0.012 \text{ to } 0.045.$
When $165.5 \le \theta < 166.5$	$(h/\lambda) \times a \text{ is } 0.0135 \text{ to } 0.045.$
When $166.5 \le \theta < 167.5$ When $167.5 \le \theta < 168.5$	$(h/\lambda) \times a \text{ is } 0.015 \text{ to } 0.045.$ $(h/\lambda) \times a \text{ is } 0.016 \text{ to } 0.045.$
When $168.5 \le \theta < 168.5$ When $168.5 \le \theta < 169.5$	$(h/\lambda) \times a$ is 0.016 to 0.045. $(h/\lambda) \times a$ is 0.0165 to 0.045.
When $169.5 \le \theta < 169.5$ When $169.5 \le \theta < 170.5$	$(h/\lambda) \times a$ is 0.0103 to 0.043. $(h/\lambda) \times a$ is 0.017 to 0.045.
When $170.5 \le 0 < 170.5$ When $170.5 \le 0 < 171.5$	$(h/\lambda) \times a$ is 0.017 to 0.045. $(h/\lambda) \times a$ is 0.0175 to 0.045.
When $171.5 \le \theta < 172.5$	$(h/\lambda) \times a$ is 0.018 to 0.045.
When $171.5 \le 0.572.5$ When $172.5 \le 0 \le 174.5$	$(h/\lambda) \times a$ is 0.0185 to 0.045.
When $174.5 \le \theta < 176.5$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.045.$
When $176.5 \le \theta \le 180$	$(h/\lambda) \times a \text{ is } 0.0195 \text{ to } 0.045.$

TABLE 10

_	For $[0.95 \le H/\lambda < 1.00]$			
	When $0 \le \theta \le 1.5$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.04.$		
	When $1.5 \le \theta \le 4.5$	$(h/\lambda) \times a \text{ is } 0.0185 \text{ to } 0.04.$		
	When $4.5 \le \theta \le 6.5$	$(h/\lambda) \times a \text{ is } 0.018 \text{ to } 0.04.$		
	When $6.5 \le \theta < 7.5$	$(h/\lambda) \times a \text{ is } 0.0175 \text{ to } 0.04.$		
	When $7.5 \le \theta < 8.5$	$(h/\lambda) \times a \text{ is } 0.017 \text{ to } 0.04.$		
	When $8.5 \le \theta \le 9.5$	$(h/\lambda) \times a$ is 0.0165 to 0.04.		

For [0.95	$\leq H/\lambda \leq 1.00$
When $9.5 \le \theta \le 10.5$	$(h/\lambda) \times a \text{ is } 0.016 \text{ to } 0.04.$
When $10.5 \le \theta \le 11.5$	$(h/\lambda) \times a \text{ is } 0.0155 \text{ to } 0.04.$
When $11.5 \le \theta \le 12.5$	$(h/\lambda) \times a \text{ is } 0.015 \text{ to } 0.04.$
When $12.5 \le \theta \le 13.5$	$(h/\lambda) \times a \text{ is } 0.014 \text{ to } 0.04.$
When $13.5 \le \theta \le 14.5$	$(h/\lambda) \times a \text{ is } 0.0135 \text{ to } 0.04.$
When $14.5 \le \theta < 15.5$	$(h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.04.$
When $15.5 \le \theta \le 16.5$	$(h/\lambda) \times a \text{ is } 0.0115 \text{ to } 0.04.$
When $16.5 \le \theta \le 17.5$	$(h/\lambda) \times a \text{ is } 0.01 \text{ to } 0.04.$
When $17.5 \le \theta \le 18.5$	$(h/\lambda) \times a \text{ is } 0.008 \text{ to } 0.04.$
When $18.5 \le \theta < 19.5$	$(h/\lambda) \times a \text{ is } 0.006 \text{ to } 0.04.$
When $19.5 \le \theta < 52.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.04.$
When $52.5 \le \theta < 53.5$	$(h/\lambda) \times a \text{ is } 0.009 \text{ to } 0.04.$
When $53.5 \le \theta < 54.5$	$(h/\lambda) \times a \text{ is } 0.0115 \text{ to } 0.04.$
When $54.5 \le \theta < 55.5$	$(h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.04.$
When $55.5 \le \theta < 56.5$	$(h/\lambda) \times a \text{ is } 0.0145 \text{ to } 0.04.$
When $56.5 \le \theta < 57.5$	$(h/\lambda) \times a \text{ is } 0.0155 \text{ to } 0.04.$
When $57.5 \le \theta < 58.5$	$(h/\lambda) \times a \text{ is } 0.0165 \text{ to } 0.04.$
When $58.5 \le \theta < 59.5$	$(h/\lambda) \times a \text{ is } 0.0175 \text{ to } 0.04.$
When $59.5 \le \theta \le 60.5$	$(h/\lambda) \times a \text{ is } 0.018 \text{ to } 0.04.$
When $60.5 \le \theta \le 61.5$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.04.$
When $61.5 \le \theta \le 62.5$	$(h/\lambda) \times a \text{ is } 0.0195 \text{ to } 0.04.$
When $62.5 \le \theta \le 63.5$	$(h/\lambda) \times a \text{ is } 0.02 \text{ to } 0.04.$
When $63.5 \le \theta \le 64.5$	$(h/\lambda) \times a \text{ is } 0.0205 \text{ to } 0.04.$
When $64.5 \le \theta \le 65.5$	$(h/\lambda) \times a \text{ is } 0.021 \text{ to } 0.04.$
When $65.5 \le \theta \le 66.5$	$(h/\lambda) \times a \text{ is } 0.0215 \text{ to } 0.04.$
When $66.5 \le \theta \le 68.5$	$(h/\lambda) \times a \text{ is } 0.022 \text{ to } 0.04.$
When $68.5 \le \theta \le 69.5$	$(h/\lambda) \times a \text{ is } 0.0225 \text{ to } 0.04.$
When $69.5 \le \theta < 71.5$	$(h/\lambda) \times a \text{ is } 0.023 \text{ to } 0.04.$
When $71.5 \le \theta < 73.5$	$(h/\lambda) \times a \text{ is } 0.0235 \text{ to } 0.04.$
When $73.5 \le \theta < 75.5$	$(h/\lambda) \times a \text{ is } 0.024 \text{ to } 0.04.$
When $75.5 \le \theta < 78.5$	$(h/\lambda) \times a \text{ is } 0.0245 \text{ to } 0.04.$
When $78.5 \le \theta \le 81.5$	$(h/\lambda) \times a \text{ is } 0.025 \text{ to } 0.04.$
When $81.5 \le \theta \le 92.5$	$(h/\lambda) \times a \text{ is } 0.0255 \text{ to } 0.04.$
When $92.5 \le \theta < 94.5$	$(h/\lambda) \times a \text{ is } 0.025 \text{ to } 0.04.$
When $94.5 \le \theta < 95.5$	$(h/\lambda) \times a \text{ is } 0.0245 \text{ to } 0.04.$
When $95.5 \le \theta < 166.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.04.$
When $166.5 \le \theta < 167.5$	$(h/\lambda) \times a \text{ is } 0.0115 \text{ to } 0.04.$
When $167.5 \le \theta \le 168.5$	$(h/\lambda) \times a \text{ is } 0.0135 \text{ to } 0.04.$
When $168.5 \le \theta \le 169.5$	$(h/\lambda) \times a \text{ is } 0.015 \text{ to } 0.04.$
When $169.5 \le \theta \le 170.5$	$(h/\lambda) \times a \text{ is } 0.0155 \text{ to } 0.04.$
When $170.5 \le \theta \le 171.5$	$(h/\lambda) \times a \text{ is } 0.0165 \text{ to } 0.04.$
When $171.5 \le \theta \le 172.5$	$(h/\lambda) \times a \text{ is } 0.017 \text{ to } 0.04.$
When $172.5 \le \theta \le 173.5$	$(h/\lambda) \times a \text{ is } 0.0175 \text{ to } 0.04.$
When $173.5 \le \theta < 175.5$	$(h/\lambda) \times a \text{ is } 0.018 \text{ to } 0.04.$
When $175.5 \le \theta \le 178.5$	$(h/\lambda) \times a \text{ is } 0.0185 \text{ to } 0.04.$
When $178.5 \le \theta \le 180$	$(h/\lambda) \times a \text{ is } 0.019 \text{ to } 0.04$

Therefore, the attenuation constant  $\alpha$  can be reduced to about  $0.06\ dB/\lambda$  or less.

When the LiTaO<sub>3</sub> has Euler angles  $(0^{\circ}\pm5^{\circ}, \theta, 0^{\circ}\pm25^{\circ})$ , the normalized thickness  $(h/\lambda)x$ a of the interdigital electrode is preferably within one of ranges shown in Tables 11 to 20 below with respect to the value of  $H/\lambda$  and the value of  $\theta$ .

TABLE 11

		For $[0.05 \le H/\lambda \le 0.15]$
	When $0 \le \theta \le 48.5$	$(h/\lambda) \times a$ does not exist.
	When $48.5 \le \theta \le 49.5$	$(h/\lambda) \times a \text{ is } 0.04 \text{ to } 0.0415.$
55	When $49.5 \le \theta \le 50.5$	$(h/\lambda) \times a \text{ is } 0.0255 \text{ to } 0.05.$
00	When $50.5 \le \theta \le 51.5$	$(h/\lambda) \times a \text{ is } 0.02 \text{ to } 0.05.$
	When $51.5 \le \theta \le 52.5$	$(h/\lambda) \times a \text{ is } 0.016 \text{ to } 0.05.$
	When $52.5 \le \theta \le 53.5$	$(h/\lambda) \times a \text{ is } 0.0135 \text{ to } 0.05.$
	When $53.5 \le \theta < 54.5$	$(h/\lambda) \times a \text{ is } 0.011 \text{ to } 0.05.$
60	When $54.5 \le \theta < 55.5$	$(h/\lambda) \times a \text{ is } 0.0095 \text{ to } 0.05.$
	When $55.5 \le \theta \le 56.5$	$(h/\lambda) \times a \text{ is } 0.008 \text{ to } 0.05.$
60	When $56.5 \le \theta \le 57.5$	$(h/\lambda) \times a \text{ is } 0.0065 \text{ to } 0.05.$
	When $57.5 \le \theta \le 58.5$	$(h/\lambda) \times a \text{ is } 0.0055 \text{ to } 0.05.$
	When $58.5 \le \theta \le 122.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.05.$
	When $122.5 \le \theta \le 123.5$	$(h/\lambda) \times a \text{ is } 0.0055 \text{ to } 0.05.$
	When $123.5 \le \theta \le 124.5$	$(h/\lambda) \times a \text{ is } 0.007 \text{ to } 0.05.$
	When $124.5 \le \theta \le 125.5$	$(h/\lambda) \times a \text{ is } 0.0055 \text{ to } 0.05.$
65	When $125.5 \le \theta \le 129.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.05.$
	When $129.5 \le \theta \le 130.5$	$(h/\lambda) \times a$ is 0.0105 to 0.05.

# 13 TABLE 11-continued

# 14 TABLE 13-continued

TABLE 11-continued		_	TABLE 13-continued		
For $[0.05 \le H/\lambda \le 0.15]$			For [0.25 ≤ H/λ < 0.35]		
When $130.5 \le \theta < 132.5$ When $132.5 \le \theta < 142.5$ When $142.5 \le \theta < 143.5$ When $143.5 \le \theta < 144.5$ When $144.5 \le \theta < 144.5$ When $146.5 \le \theta < 150.5$ When $150.5 \le \theta < 152.5$ When $152.5 \le \theta < 154.5$ When $154.5 \le \theta < 155.5$ When $155.5 \le \theta < 155.5$	$\begin{array}{l} (h/\lambda) \times a \text{ is } 0.012 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.0115 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.012 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.012 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.005 \text{ or } 0.013 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0055 \text{ or } 0.013 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0055 \text{ or } 0.0125 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0055 \text{ or } 0.0125 \text{ to } 0.05. \\ (h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0055 \text{ or } 0.0125 \text{ to } 0.0055 \text{ or } 0.0055  or$	5 -	When $44.5 \le \theta < 45.5$ When $45.5 \le \theta < 46.5$ When $46.5 \le \theta < 179.5$ When $179.5 \le \theta < 180$	$(h/\lambda) \times a$ is 0.01 to 0.05. $(h/\lambda) \times a$ is 0.006 to 0.05. $(h/\lambda) \times a$ is 0.005 to 0.05. $(h/\lambda) \times a$ is 0.005 to 0.048.	
When $156.5 \le \theta < 157.5$ When $157.5 \le \theta < 158.5$	$(h/\lambda) \times a$ is 0.003 to 0.0033 to 0.0123 to 0.05. $(h/\lambda) \times a$ is 0.005 or 0.0125 to 0.05. $(h/\lambda) \times a$ is 0.005 to 0.0055 or 0.0125 to		TA	ABLE 14	
When $157.5 \le 0 < 158.5$ When $158.5 \le \theta < 159.5$	$(h/\lambda) \times a$ is 0.005 to 0.0053 of 0.0123 to 0.05. $(h/\lambda) \times a$ is 0.005 to 0.006 or 0.0125 to 0.05.	15	For [0.3	$35 \le H/\lambda < 0.45$	
When $159.5 \le \theta < 159.5$ When $159.5 \le \theta < 160.5$ When $160.5 \le \theta < 161.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.005 \text{ or } 0.0125 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0055 \text{ or } 0.0125 \text{ to } 0.05.$	-	When $0 \le \theta < 2.5$ When $2.5 \le \theta < 3.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.045.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0475.$	
When $161.5 \le \theta \le 162.5$	$(h/\lambda) \times a$ is 0.005 to 0.0065 or 0.0125 to 0.05.		When $3.5 \le \theta < 4.5$ When $4.5 \le \theta < 5.5$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.044.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.04.$	
When $162.5 \le \theta < 163.5$ When $163.5 \le \theta < 171.5$ When $171.5 \le \theta < 172.5$	$(h/\lambda) \times a$ is 0.005 to 0.0055 or 0.0125 to 0.05. $(h/\lambda) \times a$ is 0.0125 to 0.05. $(h/\lambda) \times a$ is 0.0125 to 0.05. $(h/\lambda) \times a$ is 0.0125 to 0.0485.	20	When $4.5 \le 0 < 5.5$ When $5.5 \le 0 < 6.5$ When $6.5 \le 0 < 7.5$ When $7.5 \le 0 < 39.5$ When $39.5 \le 0 < 40.5$	$(h/\lambda) \times a$ is 0.005 to 0.0355. $(h/\lambda) \times a$ is 0.005 to 0.029. $(h/\lambda) \times a$ does not exist. $(h/\lambda) \times a$ is 0.0355 to 0.05.	
When $172.5 \le \theta < 173.5$ When $173.5 \le \theta < 174.5$ When $174.5 \le \theta < 175.5$ When $175.5 \le \theta < 176.5$ When $176.5 \le \theta < 180$	$\begin{array}{l} (h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.0455. \\ (h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.042. \\ (h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.038. \\ (h/\lambda) \times a \text{ is } 0.0125 \text{ to } 0.032. \\ (h/\lambda) \times a \text{ is } 0.013 \text{ to } 0.0145. \end{array}$	25	When $40.5 \le 0 < 40.5$ When $40.5 \le 0 < 41.5$ When $41.5 \le 0 < 42.5$ When $42.5 \le 0 < 43.5$ When $43.5 \le 0 < 180$	$(h/\lambda) \times a \text{ is } 0.0935 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.021 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.0135 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.008 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.05.$	
	TABLE 12	30	TA	ABLE 15	
Fo	or $[0.15 \le H/\lambda < 0.25]$		For [0.4	$45 \le H/\lambda < 0.55$	
When $0 \le \theta < 0.5$ When $0.5 \le \theta < 1.5$ When $1.5 \le \theta < 45.5$ When $45.5 \le \theta < 46.5$ When $46.5 \le \theta < 47.5$ When $47.5 \le \theta < 48.5$ When $48.5 \le \theta < 49.5$ When $49.5 \le \theta < 130.5$	<ul> <li>(h/λ) × a is 0.01 to 0.0345.</li> <li>(h/λ) × a is 0.014 to 0.0285.</li> <li>(h/λ) × a does not exist.</li> <li>(h/λ) × a is 0.0235 to 0.05.</li> <li>(h/λ) × a is 0.0165 to 0.05.</li> <li>(h/λ) × a is 0.0115 to 0.05.</li> <li>(h/λ) × a is 0.008 to 0.05.</li> <li>(h/λ) × a is 0.005 to 0.05.</li> </ul>	35	When $0 \le \theta < 7.5$ When $7.5 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$ When $41.5 \le \theta < 180$	$(h/\lambda) \times a$ is 0.005 to 0.045. $(h/\lambda) \times a$ is 0.006 to 0.045. $(h/\lambda) \times a$ is 0.0105 to 0.045. $(h/\lambda) \times a$ is 0.0455 to 0.045. $(h/\lambda) \times a$ is 0.0265 to 0.045. $(h/\lambda) \times a$ is 0.016 to 0.045. $(h/\lambda) \times a$ is 0.005 to 0.045.	
When $130.5 \le \theta < 131.5$ When $131.5 \le \theta < 132.5$ When $132.5 \le \theta < 142.5$	5 (h/ $\lambda$ ) × a is 0.006 to 0.05. 6 (h/ $\lambda$ ) × a is 0.007 to 0.05. (h/ $\lambda$ ) × a is 0.0075 to 0.05.	40	TA	ABLE 16	
When $142.5 \le \theta < 144.5$ When $144.5 \le \theta < 148.5$ When $148.5 \le \theta < 157.5$	$(h/\lambda) \times a \text{ is } 0.0085 \text{ to } 0.05.$		For [0.5	$55 \le H/\lambda < 0.65$	
$\begin{array}{lll} \text{When } 148.5 \leq \theta < 157.5 & (h/\lambda) \times \text{a is } 0.008 \text{ to } 0.05. \\ \text{When } 157.5 \leq \theta < 166.5 & (h/\lambda) \times \text{a is } 0.0075 \text{ to } 0.05. \\ \text{When } 166.5 \leq \theta < 169.5 & (h/\lambda) \times \text{a is } 0.0075 \text{ to } 0.05. \\ \text{When } 169.5 \leq \theta < 170.5 & (h/\lambda) \times \text{a is } 0.0065 \text{ to } 0.05. \\ \text{When } 170.5 \leq \theta < 171.5 & (h/\lambda) \times \text{a is } 0.007 \text{ to } 0.05. \\ \text{When } 171.5 \leq \theta < 172.5 & (h/\lambda) \times \text{a is } 0.007 \text{ to } 0.05. \\ \text{When } 172.5 \leq \theta < 175.5 & (h/\lambda) \times \text{a is } 0.008 \text{ to } 0.0485. \\ \text{When } 175.5 \leq \theta < 176.5 & (h/\lambda) \times \text{a is } 0.008 \text{ to } 0.0485. \\ \text{When } 176.5 \leq \theta < 177.5 & (h/\lambda) \times \text{a is } 0.0085 \text{ to } 0.0425. \\ \text{When } 177.5 \leq \theta < 178.5 & (h/\lambda) \times \text{a is } 0.0085 \text{ to } 0.0425. \\ \text{When } 178.5 \leq \theta < 179.5 & (h/\lambda) \times \text{a is } 0.0085 \text{ to } 0.0385. \\ \text{When } 179.5   [\text{M2}] \leq \theta < 180 & (h/\lambda) \times \text{a is } 0.009 \text{ to } 0.0345. \\ \end{array}$	50	When $0 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$ When $40.5 \le \theta < 180$	$(h/\lambda) \times a$ is 0.005 to 0.045. $(h/\lambda) \times a$ is 0.006 to 0.045. $(h/\lambda) \times a$ is 0.0115 to 0.045. $(h/\lambda) \times a$ is 0.0155 to 0.045. $(h/\lambda) \times a$ is 0.044 to 0.045. $(h/\lambda) \times a$ is 0.026 to 0.045. $(h/\lambda) \times a$ is 0.0155 to 0.045. $(h/\lambda) \times a$ is 0.009 to 0.045. $(h/\lambda) \times a$ is 0.005 to 0.045.		
		<b>-</b> 55	TA	ABLE 17	
	TABLE 13	-	For $[0.65 \le H/\lambda \le 0.75]$		
When $0 \le \theta < 0.5$ When $0.5 \le \theta < 1.5$ When $1.5 \le \theta < 2.5$ When $2.5 \le \theta < 3.5$ When $3.5 \le \theta < 4.5$ When $4.5 \le \theta < 5.5$ When $4.5 \le \theta < 42.5$ When $4.5 \le \theta < 43.5$ When $43.5 \le \theta < 44.5$	or $[0.25 \le H/\lambda < 0.35]$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0455.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.0445.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.041.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.037.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.032.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.025.$ $(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.023 \text{ to } 0.05.$ $(h/\lambda) \times a \text{ is } 0.023 \text{ to } 0.05.$	60	When $0 \le \theta < 7.5$ When $7.5 \le \theta < 8.5$ When $8.5   [M3] \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$ When $40.5 \le \theta < 180$	$(h/\lambda) \times a$ is 0.005 to 0.045. $(h/\lambda) \times a$ is 0.005 to 0.0435. $(h/\lambda) \times a$ is 0.005 to 0.0385. $(h/\lambda) \times a$ is 0.009 to 0.032. $(h/\lambda) \times a$ is 0.0309 to 0.045. $(h/\lambda) \times a$ is 0.0305 to 0.045. $(h/\lambda) \times a$ is 0.0185 to 0.045. $(h/\lambda) \times a$ is 0.0105 to 0.045. $(h/\lambda) \times a$ is 0.0055 to 0.045. $(h/\lambda) \times a$ is 0.0055 to 0.045.	

For $[0.75 \le H/\lambda < 0.85]$		
When $0 \le \theta < 8.5$	$(h/\lambda) \times a$ is 0.005 to 0.045.	
When $8.5 \le \theta < 9.5$	$(h/\lambda) \times a$ is 0.005 to 0.0405.	
When $9.5 \le \theta < 10.5$	$(h/\lambda) \times a$ is 0.009 to 0.035.	
When $10.5 \le \theta < 11.5$	$(h/\lambda) \times a$ is 0.017 to 0.023.	
When $11.5 \le \theta < 35.5$	$(h/\lambda) \times a$ does not exist.	
When $35.5 \le \theta < 36.5$	$(h/\lambda) \times a$ is 0.042 to 0.045.	
When $36.5 \le \theta < 37.5$	$(h/\lambda) \times a$ is 0.0245 to 0.045.	
When $37.5 \le \theta < 38.5$	$(h/\lambda) \times a$ is 0.014 to 0.045.	
When $38.5 \le \theta < 39.5$	$(h/\lambda) \times a \text{ is } 0.0075 \text{ to } 0.045.$	
When $39.5 \le \theta < 180$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.045.$	

TABLE 19

	For [0.85	$5 \le H/\lambda \le 0.95$
When $0 \le \theta < 8.5$	When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 35.5$ When $35.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$	$(h/\lambda) \times a$ is 0.007 to 0.0415. $(h/\lambda) \times a$ is 0.01 to 0.036. $(h/\lambda) \times a$ is 0.018 to 0.0255. $(h/\lambda) \times a$ does not exist. $(h/\lambda) \times a$ is 0.037 to 0.045. $(h/\lambda) \times a$ is 0.0215 to 0.045. $(h/\lambda) \times a$ is 0.012 to 0.045. $(h/\lambda) \times a$ is 0.012 to 0.045.

TABLE 20

For $[0.95 \le H/\lambda \le 1.00]$			
When $0 \le \theta < 7.5$	$(h/\lambda) \times a$ is 0.005 to 0.04.		
When $7.5 \le \theta < 8.5$	$(h/\lambda) \times a$ is 0.007 to 0.04.		
When $8.5 \le \theta < 9.5$	$(h/\lambda) \times a$ is 0.009 to 0.04.		
When $9.5 \le \theta < 10.5$	$(h/\lambda) \times a$ is 0.012 to 0.04.		
When $10.5 \le \theta < 11.5$	$(h/\lambda) \times a$ is 0.02 to 0.04.		
When $11.5 \le \theta < 35.5$	$(h/\lambda) \times a$ does not exist.		
When $35.5 \le \theta < 36.5$	$(h/\lambda) \times a$ is 0.034 to 0.04.		
When $36.5 \le \theta < 37.5$	$(h/\lambda) \times a$ is 0.0195 to 0.04.		
When $37.5 \le \theta < 38.5$	$(h/\lambda) \times a \text{ is } 0.0105 \text{ to } 0.04.$		
When $38.5 \le \theta < 180$	$(h/\lambda) \times a \text{ is } 0.005 \text{ to } 0.04.$		

In this case, the electromechanical coupling coefficient  $K^2$  can be adjusted to about 0.02 or greater and the pass band can be significantly expanded.

In preferred embodiments of the present invention, the Euler angles  $(\phi, \theta, \psi)$  may be Euler angles equivalent in boundary acoustic wave properties from Equation (A) below in a preferred Euler angle range.

$$F(\varphi, \theta, \psi) = F(60^{\circ} + \varphi, -\theta, \psi)$$
 Equation (A)  

$$= F(60^{\circ} - \varphi, -\theta, 180^{\circ} - \psi)$$
  

$$= F(\varphi, 180^{\circ} + \theta, 180^{\circ} - \psi)$$
  

$$= F(\varphi, \theta, 180^{\circ} + \psi)$$

In the boundary acoustic wave device according to a preferred embodiment the present invention, an electrode material is not particularly limited and an IDT electrode is preferably made of Pt, for example. This is effective to improve for reliability of the boundary acoustic wave device.

The IDT electrode may preferably include an Al film disposed on the first medium layer side and a Pt film disposed on the piezoelectric substrate side, for example. This reduces the insertion loss.

The IDT electrode may preferably include a Pt film disposed on the first medium layer side and an Al film disposed

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on the piezoelectric substrate side, for example. This reduces the absolute value of the temperature coefficient of frequency TCF and also the insertion loss as compared to the case of using only the Pt layer.

The IDT electrode preferably includes a metal laminate film formed by stacking a plurality of metal layers and the metal laminate film preferably includes a layer abutting the piezoelectric substrate, a layer abutting the first medium layer, and a metal layer which is located at at least one location between the metal layers and which is made of at least one material selected from the group consisting of Ti, Ni, and NiCr, for example. This increases the adhesion of the IDT electrode to the piezoelectric substrate, the adhesion of the IDT electrode to the first medium layer, and/or the adhesion of the metal layers. Therefore, the reliability of the boundary acoustic wave device is improved.

The boundary acoustic wave device according to a preferred embodiment of the present invention has a three-me-20 dium structure in which the first and second medium layers are deposited on a piezoelectric substrate. Therefore, the boundary acoustic wave device is suitable for increased frequencies and has improved reliability. The sound velocity of the first medium layer is less than the sound velocity of LiTaO<sub>3</sub>, the sound velocity of the second medium layer is greater than the sound velocity of LiTaO<sub>3</sub>, and  $(h/\lambda)$ ×a is 0.05 or less. Therefore, a transverse-mode ripple is effectively suppressed. When the LiTaO<sub>3</sub> has Euler angles (0°±5°, θ,  $0^{\circ} \pm 25^{\circ}),$  the normalized thickness (h/\lambda)×a of the interdigital electrode is within one of ranges shown in above Tables 1 to 10 with respect to the value of H/ $\lambda$  and the value of  $\theta$ . Therefore, the attenuation constant  $\alpha$  can be reduced to about 0.06  $dB/\lambda$  or less, for example. The normalized thickness  $(h/\lambda)\times a$ of the interdigital electrode is within one of ranges shown in above Tables 11 to 20 with respect to the value of  $H/\lambda$  and the value of  $\theta$ . Therefore, the electromechanical coupling coefficient  $K^2$  can be adjusted to about 0.02 or greater and the pass band can be expanded. Accordingly, a boundary acoustic wave device having outstanding resonance properties and filtering properties is provided.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are a schematic front sectional view and a schematic horizontal sectional view, respectively, of a Equation (A) 50 boundary acoustic wave device according to a preferred embodiment of the present invention.

FIG. **2** is a partial cutaway front sectional view illustrating the thickness H of a first medium layer, the thickness h of an IDT electrode, and the period  $\lambda$  of electrode fingers according to a preferred embodiment of the present invention.

FIG. 3 is a graph showing the change in propagation loss  $\alpha$  by varying the thickness of IDT electrodes in Example 1.

FIG. 4 is a graph showing the change in frequency response when using IDT electrodes which are made of Au and which have a normalized thickness (%) of about 4.0% and about 2.5%.

FIG. 5 is a graph showing the relationship between the normalized thickness  $h/\lambda$  (%) and electromechanical coefficient  $K^2$  of IDT electrodes.

FIG. **6** is a graph showing the impedance characteristics when using Au films having a normalized thickness of about 2.5% and about 3.0% as IDT electrodes.

FIG. 7 is an impedance Smith chart of a one-port type boundary acoustic wave resonator including a first medium layer which is made of  ${\rm SiO}_2$  with Euler angles (0°, 132°, 0°) and which has a normalized thickness H/ $\lambda$  of about 40% and IDT electrodes which are made of Pt and which have a normalized thickness (h/ $\lambda$ )×a of about 3.0%.

FIG. **8** is an impedance Smith chart of a one-port type boundary acoustic wave resonator including a first medium layer which is made of  $SiO_2$  with Euler angles (0°, 132°, 0°) and which has a normalized thickness H/ $\lambda$  of about 40% and IDT electrodes which are made of Pt and which have a normalized thickness (h/ $\lambda$ )×a of about 5.0%.

FIG. **9** is an impedance Smith chart of a one-port type boundary acoustic wave resonator including a first medium layer which is made of  $SiO_2$  with Euler angles (0°, 132°, 0°) and which has a normalized thickness H/ $\lambda$  of about 40% and IDT electrodes which are made of Pt and which have a normalized thickness (h/ $\lambda$ )×a of about 6.0%.

FIG. **10** is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 10% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 11 is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 20% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 12 is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 30% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 13 is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 40% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. **14** is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 50% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. **15** is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 60% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 16 is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 70% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 17 is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 80% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. **18** is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 90% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. **19** is a graph showing the distribution of the propagation loss  $\alpha$  when the normalized thickness H/ $\lambda$  (%) of an SiO<sub>2</sub> film used as a first medium layer is about 100% and  $\theta$  of

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the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness h/ $\lambda$  of IDT electrodes are varied.

FIG. 20 is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 20% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. 21 is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 30% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. 22 is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 40% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. 23 is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 50% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. **24** is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 60% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. **25** is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 70% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. **26** is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 80% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. 27 is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 90% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. **28** is a graph showing the distribution of the electromechanical coefficient  $K^2$  when the normalized thickness  $H/\lambda$  (%) of an  $SiO_2$  film used as a first medium layer is about 100% and  $\theta$  of the Euler angles (0°,  $\theta$ , 0°) of LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of IDT electrodes are varied.

FIG. **29** is a graph showing the relationship between the electromechanical coefficient  $K^2$  of boundary acoustic wave devices including IDT electrodes which are disposed on LiTaO<sub>3</sub> with Euler angles (0°, 132°,  $\psi$ °) and which are made of Au,  $\psi$ , and the normalized thickness (%) of the IDT electrodes.

FIG. 30 is a graph showing results obtained using IDT electrodes having a normalized thickness of about 3.0%.

FIG. 31 is an illustration showing the energy distribution of a conventional boundary acoustic wave device.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below with reference to the attached drawings.

FIGS. 1A and 1B are a schematic front sectional view and a schematic horizontal sectional view, respectively, of a boundary acoustic wave device according to a preferred embodiment of the present invention.

The boundary acoustic wave device 1 includes a piezoelectric substrate 2 preferably made of single-crystalline  ${\rm LiTaO_3}$ , for example. A first medium layer 3 and a second medium layer 4 are arranged on the piezoelectric substrate 2 in that order. That is, the boundary acoustic wave device 1 of this 5 preferred embodiment has a three-medium structure.

In this preferred embodiment, the first medium layer **3** is made of SiO<sub>2</sub>. The sound velocity of SiO<sub>2</sub> is about 3750 m/s. A dielectric used for the first medium layer **3** is not particularly limited and is preferably SiO<sub>2</sub>, for example. SiO<sub>2</sub> has a positive temperature coefficient of frequency and LiTaO<sub>3</sub> has a negative temperature coefficient of frequency. This enables the absolute value of the temperature coefficient of frequency to be small. Therefore, changes in properties due to temperature changes are reduced.

In this preferred embodiment, the second medium layer 4 is made of SiN. The sound velocity of SiN is about 6000 m/s. A material forming the second medium layer 4 may preferably be one having a sound velocity different from that of the dielectric forming the first medium layer 3. The dielectric is 20 preferably at least one material selected from the group consisting of SiN, SiON, AlN, AlO, Si, SiC, diamond-like carbon, and polysilicon, for example. The use of one material selected from the above group enables a boundary acoustic wave to be confined by a large waveguide effect.

IDT electrodes 5 and reflectors 6 and 7 are arranged at the interface between the piezoelectric substrate 2 and the first medium layer 3.

With reference to FIG. 1B, the reflectors 6 and 7 are arranged on both sides of the IDT electrodes 5 in the propagation direction of a boundary acoustic wave, whereby a one-port boundary acoustic wave resonator is provided.

The boundary acoustic wave device according to preferred embodiments of the present invention is not limited to the boundary acoustic wave resonator and is applicable to various 35 boundary acoustic wave apparatuses, such as boundary acoustic wave filters. Therefore, the electrode structure may be appropriately modified depending on the function of the boundary acoustic wave device.

The conventional boundary acoustic wave device disclosed 40 in WO 98/52279 has a problem in that a transverse-mode ripple occurs, as described above, when the IDT electrodes have an increased thickness or are made of a high-density metal. The inventors of the present invention have intensively studied structures for suppressing transverse-mode ripples in 45 boundary acoustic wave devices having three-medium structures. As a result, the inventors of the present invention have discovered that a transverse-mode ripple can be effectively suppressed when the sound velocity of the first medium layer 3 is less than the sound velocity of LiTaO<sub>3</sub>, the sound velocity 50 of the second medium layer 4 is greater than the sound velocity of LiTaO<sub>3</sub>, and  $(h/\lambda)$ ×a is about 0.05 or less, that is, about 5% or less, where H is the thickness of the first medium layer 3, h is the thickness of the IDT electrodes,  $\lambda$  is the period of electrode fingers of the IDT electrodes, and a is the ratio of the 55 density of the IDT electrodes to the density of Au as shown in FIG. 2. Preferred embodiments of the present invention are further described below in detail on the basis of experiments. Experiment 1

LiTaO $_3$  having Euler angles (0°, 132°, 0°) was used for 60 each piezoelectric substrate. SiO $_2$  films having a normalized thickness H/ $\lambda$  of about 0.4 were used for first medium layers. Au films having a normalized thickness h/ $\lambda$  of about 0.005 to about 0.05 were used for IDT electrodes 5. Second medium layers 4 were SiN films having a thickness of about 3000 nm, 65 that is, a normalized thickness of about 1.58 (1.58 times the wavelength, that is, 158% of the wavelength).

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The relationship between the thickness (h/ $\lambda$ ) (%) of the IDT electrodes and the propagation loss  $\alpha$  of boundary acoustic wave devices obtained as described above was determined. The expression h/ $\lambda$  (%) refers to a ratio represented by the formula (h/ $\lambda$ )×100. The results are shown in FIG. 3.

As is clear from FIG. 3, the reduction of  $h/\lambda$  from about 4.0% to about 2.5%, that is, about 0.04 to about 0.25 improves the propagation loss  $\alpha$  from about 0.024 to about 0.011, that is, by about 0.013 (dB/ $\lambda$ ).

Longitudinal mode resonator-type filters including Au films, each having a normalized thickness  $h/\lambda$  (%) of about 2.5% or about 4.0%, as IDT electrodes were measured for frequency response. The results are shown in FIG. 4. As is clear from FIG. 4, the longitudinal mode resonator-type filter including the Au films having a normalized thickness  $h/\lambda$  (%) of about 4.0% has a minimum insertion loss of about 2.55 dB and the longitudinal mode resonator-type filter including the Au films having a smaller normalized thickness  $h/\lambda$  (%) of about 2.5% has an improved minimum insertion loss of about 2.35 dB.

This preferred embodiment of the present invention shows that when the IDT electrodes are made of Au, which is a relatively heavy metal, and a normalized thickness  $h/\lambda$  thereof is 4.0% or less, the reduction of the normalized thickness  $h/\lambda$  improves the propagation loss  $\alpha$ . Experiment 2

In boundary acoustic wave devices 1 having the same medium structure as that prepared in Experiment 1, the variation of the electromechanical coupling coefficient K<sup>2</sup> was determined by varying the normalized thickness  $h/\lambda$  (%) of IDT electrodes made of Au within the range of about 0.5% to about 5% in the same manner as that described in Experiment 1. The results are shown in FIG. 5. As is clear from FIG. 5, a reduction of the normalized thickness  $h/\lambda$  (%) of the IDT electrodes from about 3.0% to about 2.5% reduces the electromechanical coupling coefficient K<sup>2</sup> from about 6.45% to about 6.3%. That is, the electromechanical coupling coefficient K<sup>2</sup> can be controlled by adjusting the normalized thickness  $h/\lambda$  (%) of the IDT electrodes 5. FIG. 6 is a graph showing the impedance characteristics of boundary acoustic wave devices including the same structure as described above except that IDT electrodes 5 made of Au had a normalized thickness  $h/\lambda$  (%) of about 2.5% or about 3.0%.

As is clear from FIG. **6**, a variation of the normalized thickness  $h/\lambda$  (%) of the IDT electrodes from about 3.0% to about 2.5% improves the band width ratio by about 0.2%. It is known that the equation (electromechanical coupling coefficient)=(band width ratio)×2 is substantially satisfied for the electromechanical coupling coefficient and the band width ratio. This shows that an increase of the electromechanical coupling coefficient  $K^2$  increases the band width ratio. Experiment 3

In Experiment 3, the dependence of the propagation loss  $\alpha$  and the electromechanical coupling coefficient  $K^2$  on the normalized thickness  $h/\lambda$  of IDT electrodes was determined by varying  $\theta$  of Euler angles  $(0^\circ, \theta, 0^\circ)$  of the LiTaO<sub>3</sub> and the normalized thickness  $h/\lambda$  of the IDT electrodes on the basis of the results of Experiments 1 and 2. The results are shown in FIGS. 10 to 28.

FIGS. 10 to 19 are graphs showing the relationship between  $\theta$ , the normalized thickness h/ $\lambda$  of IDT electrodes, and the propagation loss  $\alpha$ ,  $\theta$  being determined when the normalized thickness H/ $\lambda$  (%) of SiO<sub>2</sub> used for a first medium layer is about 10%, about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 90%, or about 100%.

40

45

50

0-0.01

0.09-0.1

0.08-0.09

0.07-0.08

0.06-0.07

0.05-0.06

0.04-0.05

0.03-0.04

0.02-0.03

0.01-0.02

0.09-0.1

0.08-0.09

0.07-0.08

0.06-0.07

0.05-0.06

0-0.01

Symbols indicating regions surrounded by contour lines in FIGS. 10 to 19 each represent the range of the propagation loss of a corresponding one of the regions. For example, the propagation loss α of each of Regions A13 to A20 corresponds to that of A13 to A20 shown in Table 21 below. That is, 5 the propagation loss  $\alpha$  of Region A13 is about 0.07 to about  $0.08 \, (dB/\lambda)$ . As is clear from FIG. 10, the propagation loss of Region A13 is about 0.07 to about 0.08 and Region A13, Region A14, Region A15, Region A16, Region A17, Region A18, Region A19, and Region A20 are arranged in descend- 10 ing order of propagation loss  $\alpha$  in that order.

FIG. 10 illustrates that in order to adjust the propagation loss  $\alpha$  to about 0.06 dB/ $\lambda$  or less, Regions A15 to A20 may be used. That is,  $\boldsymbol{\theta}$  of the Euler angles and the normalized thickness  $h/\lambda$  of the IDT electrodes may be selected such that 15 Regions A15 to A20 are obtained.

Likewise, FIGS. 11 to 19 illustrate that the propagation loss  $\alpha$  can be adjusted to about 0.06 dB/ $\lambda$  or less in such a manner that  $\theta$  of the Euler angles and the normalized thickness h/ $\lambda$  of the IDT electrodes are selected depending on the normalized 20 thickness  $H/\lambda$  (%) of SiO<sub>2</sub> used for the first medium layer 3.

When  $h/\lambda$  is greater than about 0.05 in FIGS. 12 and 13, boundary acoustic waves are non-leaky and therefore the propagation loss  $\alpha$  is 0. Likewise, when  $h/\lambda$  is greater than about 0.045 in FIGS. 14 to 18 and  $h/\lambda$  is greater than about 25 0.04 in FIG. 19, boundary acoustic waves are non-leaky and, therefore, the propagation loss  $\alpha$  is 0. That is, although boundary acoustic waves are non-leaky at an electrode thickness of about 6% or greater as shown in FIG. 3, an increase in the normalized thickness of an SiO<sub>2</sub> layer enables a boundary 30 acoustic wave to be non-leaky at a smaller electrode thickness.

TABLE 21

Propagation loss $\alpha$		
A13	0.07-0.08	
A14	0.06-0.07	
A15	0.05-0.06	
A16	0.04-0.05	
A17	0.03-0.04	
A18	0.02-0.03	
A19	0.01-0.02	
A20	0-0.01	
A21	0.09-0.1	
A22	0.08-0.09	
A23	0.07-0.08	
A24	0.06-0.07	
A25	0.05-0.06	
A26	0.04-0.05	
A27	0.03-0.04	
A28	0.02-0.03	
A29	0.01-0.02	
A30	0-0.01	
A31	0.09-0.1	
A32	0.08-0.09	
A33	0.07-0.08	
A34	0.06-0.07	
A35	0.05-0.06	
A36	0.04-0.05	
A37	0.03-0.04	
A38	0.02-0.03	
A39	0.01-0.02	
A40	0-0.01	
A41	0.09-0.1	
A42	0.08-0.09	
A43	0.07-0.08	
A44	0.06-0.07	
A45	0.05-0.06	
A46	0.04-0.05	
A47	0.03-0.04	
A48	0.02-0.03	
A49	0.01-0.02	

TABLE 21-continued

Propagation loss α

A50

A51

A52

A53

A54

A55

A56

A57

A58

A59

**A**60

A61

A62

A63

A64

A65

A66 A67 A68 A67 A68 A68  0.02-0.03 A69 0.01-0.02 A70 A71 0.09-0.1 A71 A72 0.08-0.09 A73 A74 A75 A75 A76 A77 A75 A77 A77 A78 A78 A79 A79 A79 A80 A81 A81 A81 A81 A82 A84 A84 A85 A84 A85 A85 A84 A85 A86 A87 A88 A84 A88 A88 A89 A89 A89 A91 A91 A92 A90 A93 A99 A93 A94 A96 A96 A97 A95 A97 A95 A97 A95 A97	A05	0.05-0.06	
A68 A69 O.01-0.02 A70 O-0.01 A71 O.09-0.1 A72 O.08-0.09 A73 O.07-0.08 A74 O.06-0.07 A75 O.05-0.06 A76 O.04-0.05 A77 O.03-0.04 A78 O.02-0.03 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.09-0.1 A89 O.01-0.02 A80 O-0.01 A91 O.09-0.1 A92 O.08-0.09 A93 O.01-0.02 A90 A93 O.07-0.08 A94 O.06-0.07 A95 O.08-0.09 A93 A99 O.01-0.02 A90 A93 O.07-0.08 A94 O.06-0.07 A95 O.08-0.09 A93 A99 O.01-0.02 A90 A93 O.07-0.08 A94 O.06-0.07 A95 O.08-0.09 A93 A99 O.01-0.02 A90 A91 A92 O.08-0.09 A93 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.09-0.09 B15 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02	A66	0.04-0.05	
A69 A70 O-0.01 A71 O.09-0.1 A71 O.09-0.1 A72 O.08-0.09 A73 O.07-0.08 A74 O.06-0.07 A75 O.05-0.06 A76 O.04-0.05 A77 O.03-0.04 A78 O.02-0.03 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.02-0.03 A89 O.01-0.02 A90 O-0.01 A91 O.09-0.1 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.06-0.07 B15 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02	A67	0.03-0.04	
A69 A70 O-0.01 A71 O.09-0.1 A71 O.09-0.1 A72 O.08-0.09 A73 O.07-0.08 A74 O.06-0.07 A75 O.05-0.06 A76 O.04-0.05 A77 O.03-0.04 A78 O.02-0.03 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.02-0.03 A89 O.01-0.02 A90 O-0.01 A91 O.09-0.1 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.06-0.07 B15 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02	A68	0.02-0.03	
A71 A72 0.08-0.09 A73 0.07-0.08 A74 0.06-0.07 A75 0.05-0.06 A76 0.04-0.05 A77 0.03-0.04 A78 0.02-0.03 A79 0.01-0.02 A80 0-0.01 A81 0.09-0.1 A82 0.08-0.09 A83 0.07-0.08 A84 0.06-0.07 A85 0.05-0.06 A86 0.04-0.05 A87 0.03-0.04 A88 0.02-0.03 A89 0.01-0.02 A90 0-0.01 A91 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 A96 0.04-0.05 A97 0.05-0.06 A98 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 A98 0.02-0.03 A99 0.01-0.02 A90 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02		0.01-0.02	
A71 A72 0.08-0.09 A73 0.07-0.08 A74 0.06-0.07 A75 0.05-0.06 A76 0.04-0.05 A77 0.03-0.04 A78 0.02-0.03 A79 0.01-0.02 A80 0-0.01 A81 0.09-0.1 A82 0.08-0.09 A83 0.07-0.08 A84 0.06-0.07 A85 0.05-0.06 A86 0.04-0.05 A87 0.03-0.04 A88 0.02-0.03 A89 0.01-0.02 A90 0-0.01 A91 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 A96 0.04-0.05 A97 0.05-0.06 A98 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 A98 0.02-0.03 A99 0.01-0.02 A90 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02	A70	0-0.01	
A72	A71	0.09-0.1	
A73 A74 A75 A75 A75 A76 A76 A77 A77 A77 A77 A78 A78 A78 A79 A80 A80 A90 A81 A82 A82 A83 A84 A84 A84 A85 A85 A86 A86 A86 A87 A87 A88 A87 A88 A87 A88 A89 A91 A91 A91 A92 A93 A93 A93 A94 A94 A95 A95 A96 A96 A96 A97 A95 A97 A97 A98 A98 A99 A97 A98 A99 A97 A98 A99 A99 B11 B12 A99 B13 B14 A06-0.07 B15 B16 A06-0.07 B15 B17 A03-0.04 B18 B18 A92-0.03 B19 A90 A90 A90 A90 A90 A90 A90 A90 A90 A9		0.08-0.09	
A74 A75 A75 A76 A76 A76 A77  A77  A78  A78  A78  A7			
A75 A76 A76 A77 A77 A78 A77 A78 A78 A79 A79 A80 A79 A80 A81 A81 A82 A82 A83 A84 A84 A84 A85 A85 A86 A86 A86 A87 A88 A89 A89 A81 A89 A90 A90 A90 A91 A92 A90 A93 A99 A93 A94 A94 A96 A96 A96 A97 A95 A97 A98 A98 A98 A99 A91 A98 A99 A91 A98 A99 A91 A98 A99 A91 A99 B11 B12 A99 B13 B14 A06-0.07 B15 B16 A06-0.07 B15 B16 B17 A03-0.04 B18 B18 A02-0.03 B19 A01-0.02			
A76 A77 A78 O.03-0.04 A78 O.02-0.03 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.02-0.03 A89 O.01-0.02 A90 A91 O.09-0.1 A91 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 A96 O.04-0.05 A97 O.05-0.06 A96 O.04-0.05 A97 O.05-0.06 A96 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A90 D.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.09-0.1 B15 O.05-0.06 B16 O.04-0.05 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02			
A77 A78 A78 O.03-0.04 A78 O.02-0.03 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.02-0.03 A89 O.01-0.02 A90 O-0.01 A91 O.09-0.1 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.09-0.1 B15 O.05-0.06 B16 O.04-0.05 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02			
A78 A79 O.01-0.02 A80 O-0.01 A81 O.09-0.1 A82 O.08-0.09 A83 O.07-0.08 A84 O.06-0.07 A85 O.05-0.06 A86 O.04-0.05 A87 O.03-0.04 A88 O.02-0.03 A89 O.01-0.02 A90 O-0.01 A91 O.09-0.1 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.01-0.02 A90 O-0.01 A91 D.09-0.1 A92 O.08-0.09 A93 O.07-0.08 A94 O.06-0.07 A95 O.05-0.06 A96 O.04-0.05 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.09-0.09 B13 O.07-0.08 B14 O.06-0.07 B15 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02			
A79 A80  A81  O-0.01  A81  O.09-0.1  A82  O.08-0.09  A83  O.07-0.08  A84  O.06-0.07  A85  O.04-0.05  A87  O.03-0.04  A88  O.02-0.03  A89  O-0.01  A91  O.09-0.1  A92  O.08-0.09  A93  O.07-0.08  A94  O.06-0.07  A95  O.05-0.06  A96  O.04-0.05  A97  O.05-0.06  A98  O.04-0.05  A97  O.05-0.06  A98  O.04-0.05  A97  O.03-0.04  A98  O.02-0.03  A99  O.01-0.02  A90  O-0.01  B11  O.09-0.1  B12  O.08-0.09  B13  O.07-0.08  B14  O.06-0.07  B15  O.05-0.06  B16  O.04-0.05  B17  O.03-0.04  B18  O.05-0.06  B16  O.04-0.05  B17  O.03-0.04  B18  O.05-0.06  B16  O.04-0.05  B17  O.03-0.04  B18  O.05-0.06  B19  O.05-0.06  B10			
A80 0-0.01 A81 0.09-0.1 A82 0.08-0.09 A83 0.07-0.08 A84 0.06-0.07 A85 0.05-0.06 A86 0.04-0.05 A87 0.03-0.04 A88 0.02-0.03 A89 0.01-0.02 A90 0-0.01 A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A90 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.08-0.09 B15 0.05-0.06 B16 0.04-0.05 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A81			
A82			
A83  A84  A85  A86  A86  A87  A87  A88  A88  A88  A89  A89  A91  A91  A92  A93  A93  A94  A94  A96  A96  A97  A98  A97  A98  A97  A98  A98  A97  A98  A98			
A84 0.06-0.07 A85 0.05-0.06 A86 0.04-0.05 A87 0.03-0.04 A88 0.02-0.03 A89 0.01-0.02 A90 0-0.01 A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A85			
A86  A87  A88  0.03-0.04  A88  0.02-0.03  A89  0.01-0.02  A90  0-0.01  A91  A92  0.08-0.09  A93  0.07-0.08  A94  0.06-0.07  A95  0.05-0.06  A96  0.04-0.05  A97  0.03-0.04  A98  0.02-0.03  A99  0.01-0.02  A100  0-0.01  B11  0.09-0.1  B12  0.08-0.09  B13  0.07-0.08  B14  0.06-0.07  B15  0.07-0.08  B16  0.04-0.05  B17  0.03-0.04  B18  0.07-0.08			
A87  A88  0.03-0.04  A88  0.02-0.03  A89  0.01-0.02  A90  0-0.01  A91  0.09-0.1  A92  0.08-0.09  A93  0.07-0.08  A94  0.06-0.07  A95  0.05-0.06  A96  0.04-0.05  A97  0.03-0.04  A98  0.02-0.03  A99  0.01-0.02  A100  0-0.01  B11  0.09-0.1  B12  0.08-0.09  B13  0.07-0.08  B14  0.06-0.07  B15  0.05-0.06  B16  0.04-0.05  B17  0.03-0.04  B18  0.02-0.03			
A88 0.02-0.03 A89 0.01-0.02 A90 0-0.01 A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A89 0.01-0.02 A90 0-0.01 A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A90 0-0.01 A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A91 0.09-0.1 A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A92 0.08-0.09 A93 0.07-0.08 A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A93 A94 A95 A95 A96 A96 A97 A97 A98 A98 A98 A99 A100 B11 B12 A100 B12 A100 B13 B14 A100 B14 A100 B15 B16 A100 B16 B16 A100 B17 B17 B18			
A94 0.06-0.07 A95 0.05-0.06 A96 0.04-0.05 A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A95			
A96 A97 O.03-0.04 A98 O.02-0.03 A99 O.01-0.02 A100 O-0.01 B11 O.09-0.1 B12 O.08-0.09 B13 O.07-0.08 B14 O.06-0.07 B15 O.05-0.06 B16 O.04-0.05 B17 O.03-0.04 B18 O.02-0.03 B19 O.01-0.02			
A97 0.03-0.04 A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A98 0.02-0.03 A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A99 0.01-0.02 A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
A100 0-0.01 B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B11 0.09-0.1 B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B12 0.08-0.09 B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B13 0.07-0.08 B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B14 0.06-0.07 B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B15 0.05-0.06 B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B16 0.04-0.05 B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B17 0.03-0.04 B18 0.02-0.03 B19 0.01-0.02			
B18 0.02-0.03 B19 0.01-0.02			
B19 0.01-0.02			
V 0.01			
	D20	0 0.01	

FIGS. 10 to 19 illustrate that  $\theta$  of the Euler angles and the normalized thickness h/λ of the IDT electrodes may be selected from ranges shown in Tables 23 to 32 depending on the normalized thickness  $H/\lambda$  of  $SiO_2$  films such that the propagation loss  $\alpha$  can be reduced to about 0.06 dB/ $\lambda$  or less.

FIGS. 20 to 28 are graphs showing how the electromechanical coupling coefficient  $K^2$  varies depending on  $\theta$  of Euler angles  $(0^{\circ}, \theta, 0^{\circ})$  and the normalized thickness  $h/\lambda$  of IDT electrodes when the normalized thickness  $H/\lambda$  (%) of SiO<sub>2</sub> films is about 20%, about 30%, about 40%, about 50%, 65 about 60%, about 70%, about 80%, about 90%, or about

100%. Regions B21 to B100 and C11 to C30 shown in FIGS. 20 to 28 each indicate the range of the electromechanical

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coupling coefficient  $K^2$  shown in Table 22 below. For example, Region B21 in Table 22 corresponds to Region B21 in FIG. **20** and indicates that the electromechanical coupling coefficient  $K^2$  ranges from about 0.09 to about 0.1.

FIGS. 20 to 28 illustrate that  $\theta$  of the Euler angles that are necessary to obtain an electromechanical coupling coefficient  $K^2$  of about 2% or greater and the normalized thickness h/ $\lambda$  of the IDT electrodes may be selected depending on the normalized thickness H/ $\lambda$  of the SiO $_2$  films.

TABLE 22

Elect	romechanical coupling coefficient K <sup>2</sup>
B21	0.09-0.1
B22	0.08-0.09
B23	0.07-0.08
B24	0.06-0.07
B25 B26	0.05-0.06 0.04-0.05
B27	0.03-0.04
B28	0.02-0.03
B29	0.01-0.02
B30	0-0.01
B31	0.09-0.1
B32	0.08-0.09
B33	0.07-0.08
B34	0.06-0.07
B35	0.05-0.06
B36	0.04-0.05
B37	0.03-0.04
B38	0.02-0.03
B39	0.01-0.02
B40	0-0.01
B41	0.09-0.1
B42	0.08-0.09
B43	0.07-0.08
B44	0.06-0.07
B45	0.05-0.06
B46	0.04-0.05
B47	0.03-0.04
B48	0.02-0.03
B49 B50	0.01-0.02 0-0.01
B51	0.09-0.1
B52	0.08-0.09
B53	0.07-0.08
B54	0.06-0.07
B55	0.05-0.06
B56	0.04-0.05
B57	0.03-0.04
B58	0.02-0.03
B59	0.01-0.02
B60	0-0.01
B61	0.09-0.1
B62	0.08-0.09
B63	0.07-0.08
B64	0.06-0.07
B65	0.05-0.06
B66	0.04-0.05
B67	0.03-0.04
B68	0.02-0.03 0.01-0.02
B69 B70	0.01-0.02
B71	0.09-0.1
B72	0.08-0.09
B73	0.07-0.08
B74	0.06-0.07
B75	0.05-0.06
B76	0.04-0.05
B77	0.03-0.04
B78	0.02-0.03
B79	0.01-0.02
B80	0-0.01
B81	0.09-0.1
B82	0.08-0.09
B83	0.07-0.08
B84	0.06-0.07
B85	0.05-0.06

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TABLE 22-continued

	Electromechanical	Electromechanical coupling coefficient K <sup>2</sup>		
	B86	0.04-0.05		
5	B87	0.03-0.04		
	B88	0.02-0.03		
	B89	0.01-0.02		
	B90	0-0.01		
	B91	0.09-0.1		
	B92	0.08-0.09		
10	B93	0.07-0.08		
	B94	0.06-0.07		
	B95	0.05-0.06		
	B96	0.04-0.05		
	B97	0.03-0.04		
	B98	0.02-0.03		
15	B99	0.01-0.02		
13	B100	0-0.01		
	C11	0.09-0.1		
	C12	0.08-0.09		
	C13	0.07-0.08		
	C14	0.06-0.07		
• •	C15	0.05-0.06		
20	C16	0.04-0.05		
	C17	0.03-0.04		
	C18	0.02-0.03		
	C19	0.01-0.02		
	C20	0-0.01		

The variation of the electromechanical coupling coefficient  $K^2$  was determined such that the Euler angles of LiTaO3 were set to (0°, 132°,  $\psi$ ) and  $\psi$  of the Euler angles and the normalized thickness h/ $\!\lambda$  of IDT electrodes were varied.

FIG. 29 is a graph showing the relationship between  $\psi$  of the Euler angles, the electromechanical coupling coefficient  $K^2$ , and the normalized thickness (h/ $\lambda$ ) (%) of the IDT electrodes. FIG. 29 illustrates that in order to adjust the electromechanical coupling coefficient  $K^2$  to about 2% or greater,  $\psi$  thereof and the normalized thickness h/ $\lambda$  of the IDT electrodes may be set within a range where  $K^2$  is about 0.02 or greater.

FIG. 30 is a graph showing one of a plurality of curves shown in FIG. 29 and which represents that the normalized thickness of IDT electrodes is about 3.0%. FIG. 29 shows results obtained from IDT electrodes having a normalized thickness of about 0.5% to about 5.0%. However, the results shown in FIG. 29 are not readily apparent. Therefore, the curve representing that the normalized thickness of IDT electrodes is about 3.0% has been selected and shown in FIG. 30.

FIG. 30 illustrates that  $K^2$  can be adjusted to about 0.02 or greater when  $\psi$  of the Euler angles is within the range of about  $0^{\circ}+25^{\circ}$ 

From the results shown in FIGS. 10 to 19, the propagation loss  $\alpha$  can be adjusted to about 0.06 or less by selecting  $\theta$  of the Euler angles and the normalized thickness  $h/\lambda$  of IDT electrodes as shown in Table 23 when the normalized thickness  $H/\lambda$  of SiO<sub>2</sub> is about 0.05 to less than about 0.15.

TABLE 23

		11 11 12 23	
		For $[0.05 \le H/\lambda \le 0.15]$	
	When $0 \le \theta < 75.5$	$h/\lambda$ is 0.005 to 0.05.	
	When $75.5 \le \theta < 76.5$	$h/\lambda$ is 0.005 to 0.014 or 0.021 to 0.05.	
60	When $76.5 \le \theta < 77.5$	$h/\lambda$ is 0.005 to 0.014 or 0.022 to 0.05.	
	When $77.5 \le \theta \le 78.5$	$h/\lambda$ is 0.005 to 0.0135 or 0.023 to 0.05.	
	When $78.5 \le \theta < 79.5$	$h/\lambda$ is 0.005 to 0.013 or 0.024 to 0.05.	
	When $79.5 \le \theta \le 80.5$	$h/\lambda$ is 0.005 to 0.013 or 0.025 to 0.05.	
	When $80.5 \le \theta \le 81.5$	$h/\lambda$ is 0.005 to 0.013 or 0.0255 to 0.05.	
	When $81.5 \le \theta \le 82.5$	$h/\lambda$ is 0.005 to 0.013 or 0.026 to 0.05.	
65	When $82.5 \le \theta \le 83.5$	$h/\lambda$ is 0.005 to 0.013 or 0.0265 to 0.05.	
	When $83.5 \le \theta \le 84.5$	$h/\lambda$ is 0.005 to 0.013 or 0.027 to 0.05.	

TABLE 23-continued

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TABLE 24-continued

	For $[0.05 \le H/\lambda \le 0.15]$
When 84.5 ≤ 0 < 85.5 When 85.5 ≤ 0 < 86.5 When 86.5 ≤ 0 < 87.5 When 87.5 ≤ 0 < 88.5 When 88.5 ≤ 0 < 90.5 When 90.5 ≤ 0 < 91.5 When 91.5 ≤ 0 < 92.5 When 91.5 ≤ 0 < 92.5 When 94.5 ≤ 0 < 95.5 When 95.5 ≤ 0 < 96.5 When 95.5 ≤ 0 < 97.5 When 97.5 ≤ 0 < 98.5 When 98.5 ≤ 0 < 100.5 When 99.5 ≤ 0 < 100.5 When 100.5 ≤ 0 < 101.5 When 101.5 ≤ 0 < 101.5	For $[0.05 \le H/\lambda < 0.15]$ $h/\lambda$ is $0.005$ to $0.013$ or $0.0275$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.013$ or $0.028$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.013$ or $0.028$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.0135$ or $0.029$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.0135$ or $0.029$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.0135$ or $0.029$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.014$ or $0.03$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.014$ or $0.0305$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.0145$ or $0.0305$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.0145$ or $0.031$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.015$ or $0.031$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.015$ or $0.031$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.015$ or $0.0315$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.016$ or $0.0315$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.017$ or $0.032$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.017$ or $0.032$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.017$ or $0.032$ to $0.05$ . $h/\lambda$ is $0.005$ to $0.018$ or $0.0325$ to $0.05$ .
When $102.5 \le \theta < 103.5$ When $103.5 \le \theta < 104.5$ When $104.5 \le \theta < 105.5$ When $105.5 \le \theta < 106.5$ When $106.5 \le \theta < 107.5$ When $107.5 \le \theta < 108.5$ When $108.5 \le \theta < 109.5$ When $109.5 \le \theta < 110.5$ When $110.5 \le \theta < 111.5$ When $111.5 \le \theta < 112.5$ When $112.5 \le \theta < 180$	h/λ is 0.005 to 0.019 or 0.0325 to 0.05. h/λ is 0.005 to 0.019 or 0.0325 to 0.05. h/λ is 0.005 to 0.0195 or 0.0325 to 0.05. h/λ is 0.005 to 0.0205 or 0.033 to 0.05. h/λ is 0.005 to 0.0215 or 0.033 to 0.05. h/λ is 0.005 to 0.0225 or 0.033 to 0.05. h/λ is 0.005 to 0.0225 or 0.033 to 0.05. h/λ is 0.005 to 0.024 or 0.0325 to 0.05. h/λ is 0.005 to 0.024 or 0.0325 to 0.05. h/λ is 0.005 to 0.028 or 0.032 to 0.05. h/λ is 0.005 to 0.028 or 0.032 to 0.05. h/λ is 0.005 to 0.028 or 0.032 to 0.05. h/λ is 0.005 to 0.0295 or 0.0305 to 0.05. h/λ is 0.005 to 0.0295 or 0.0305 to 0.05.

Likewise, the propagation loss  $\alpha$  can be adjusted to about 0.06 or less by selecting  $\theta$  of the Euler angles and the normalized thickness h/ $\lambda$  of IDT electrodes as shown in Tables 24 to 32 when the normalized thickness H/ $\lambda$  of SiO $_2$  films is about 0.15 to less than about 0.25, about 0.25 to less than about 0.35, about 0.35 to less than about 0.45, about 0.45 to less than about 0.55, about 0.55 to less than about 0.65, about 0.65 to less than about 0.75, about 0.75 to less than about 0.85, about 0.85 to less than about 0.95, or about 0.95 to less than about 1.00.

TABLE 24

	For $[0.15 \le H/\lambda < 0.25]$	
When $0 \le \theta \le 1.5$	$h/\lambda$ is 0.024 to 0.05.	
When $1.5 \le \theta \le 3.5$	$h/\lambda$ is 0.0235 to 0.05.	
When $3.5 \le \theta \le 4.5$	$h/\lambda$ is 0.023 to 0.05.	
When $4.5 \le \theta \le 5.5$	$h/\lambda$ is 0.0225 to 0.05.	
When $5.5 \le \theta \le 6.5$	$h/\lambda$ is 0.022 to 0.05.	
When $6.5 \le \theta < 7.5$	$h/\lambda$ is 0.0215 to 0.05.	
When $7.5 \le \theta \le 8.5$	$h/\lambda$ is 0.021 to 0.05.	
When $8.5 \le \theta < 9.5$	$h/\lambda$ is 0.02 to 0.05.	
When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.0195 to 0.05.	
When $10.5 \le \theta \le 11.5$	$h/\lambda$ is 0.0185 to 0.05.	
When $11.5 \le \theta \le 12.5$	$h/\lambda$ is 0.0175 to 0.05.	
When $12.5 \le \theta \le 13.5$	$h/\lambda$ is 0.0165 to 0.05.	
When $13.5 \le \theta \le 14.5$	$h/\lambda$ is 0.015 to 0.05.	
When $14.5 \le \theta \le 15.5$	$h/\lambda$ is 0.013 to 0.05.	
When $15.5 \le \theta \le 16.5$	$h/\lambda$ is 0.011 to 0.05.	
When $16.5 \le \theta \le 54.5$	$h/\lambda$ is 0.005 to 0.05.	
When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.0125 to 0.05.	
When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.0155 to 0.05.	
When $56.5 \le \theta \le 57.5$	$h/\lambda$ is 0.017 to 0.05.	
When $57.5 \le \theta < 58.5$	$h/\lambda$ is 0.0185 to 0.05.	
When $58.5 \le \theta < 59.5$	$h/\lambda$ is 0.0195 to 0.05.	
When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.0205 to 0.05.	
When $60.5 \le \theta \le 61.5$	$h/\lambda$ is 0.0215 to 0.05.	
When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.0225 to 0.05.	
When $62.5 \le \theta \le 63.5$	$h/\lambda$ is 0.023 to 0.05.	
When $63.5 \le \theta \le 64.5$	$h/\lambda$ is 0.0235 to 0.05.	
When $64.5 \le \theta \le 65.5$	$h/\lambda$ is 0.0245 to 0.05.	
When $65.5 \le \theta \le 66.5$	$h/\lambda$ is 0.025 to 0.05.	
When $66.5 \le \theta \le 67.5$	$h/\lambda$ is 0.0255 to 0.05.	
When $67.5 \le \theta \le 68.5$	$h/\lambda$ is 0.026 to 0.05.	

		For $[0.15 \le H/\lambda \le 0.25]$
	When $68.5 \le \theta \le 69.5$	h/λ is 0.0265 to 0.05.
5	When $69.5 \le \theta < 70.5$	$h/\lambda$ is 0.027 to 0.05.
	When $70.5 \le \theta \le 72.5$	$h/\lambda$ is 0.0275 to 0.05.
	When $72.5 \le \theta < 73.5$	$h/\lambda$ is 0.028 to 0.05.
	When $73.5 \le \theta < 74.5$	$h/\lambda$ is 0.0285 to 0.05.
	When $74.5 \le \theta < 76.5$	$h/\lambda$ is 0.029 to 0.05.
	When $76.5 \le \theta < 78.5$	$h/\lambda$ is 0.0295 to 0.05.
10	When $78.5 \le \theta < 79.5$	$h/\lambda$ is 0.03 to 0.05.
	When $79.5 \le \theta \le 81.5$	$h/\lambda$ is 0.0305 to 0.05.
	When $81.5 \le \theta \le 83.5$	$h/\lambda$ is 0.031 to 0.05.
	When $83.5 \le \theta \le 86.5$	$h/\lambda$ is 0.0315 to 0.05.
	When $86.5 \le \theta \le 88.5$	$h/\lambda$ is 0.032 to 0.05.
	When $88.5 \le \theta \le 92.5$	$h/\lambda$ is 0.0325 to 0.05.
1.5	When $92.5 \le \theta < 97.5$	$h/\lambda$ is 0.033 to 0.05.
15	When $97.5 \le \theta < 98.5$	$h/\lambda$ is 0.005 or 0.0335 to 0.05.
	When $98.5 \le \theta < 99.5$	$h/\lambda$ is 0.005 to 0.006 or 0.0335 to 0.05.
	When $99.5 \le \theta \le 100.5$	$h/\lambda$ is 0.005 to 0.0065 or 0.0335 to 0.05.
	When $100.5 \le \theta \le 101.5$	$h/\lambda$ is 0.005 to 0.007 or 0.0335 to 0.05.
	When $101.5 \le \theta < 102.5$	$h/\lambda$ is 0.005 to 0.0075 or 0.0335 to 0.05.
	When $102.5 \le \theta < 103.5$	$h/\lambda$ is 0.005 to 0.0085 or 0.0335 to 0.05.
20	When $103.5 \le \theta \le 104.5$	$h/\lambda$ is 0.005 to 0.009 or 0.0335 to 0.05.
	When $104.5 \le \theta \le 105.5$	$h/\lambda$ is 0.005 to 0.01 or 0.0335 to 0.05.
	When $105.5 \le \theta < 106.5$	$h/\lambda$ is 0.005 to 0.011 or 0.0335 to 0.05.
	When $106.5 \le \theta < 107.5$	$h/\lambda$ is 0.005 to 0.012 or 0.0335 to 0.05.
	When $107.5 \le \theta \le 108.5$	$h/\lambda$ is 0.005 to 0.0125 or 0.0335 to 0.05.
	When $108.5 \le \theta \le 109.5$	$h/\lambda$ is 0.005 to 0.0135 or 0.033 to 0.05.
25	When $109.5 \le \theta \le 110.5$	$h/\lambda$ is 0.005 to 0.0145 or 0.033 to 0.05.
	When $110.5 \le \theta \le 111.5$	$h/\lambda$ is 0.005 to 0.016 or 0.0325 to 0.05.
	When $111.5 \le \theta \le 112.5$	$h/\lambda$ is 0.005 to 0.0175 or 0.0325 to 0.05.
	When $112.5 \le \theta \le 113.5$	$h/\lambda$ is 0.005 to 0.019 or 0.032 to 0.05.
	When $113.5 \le \theta \le 114.5$	$h/\lambda$ is 0.005 to 0.0215 or 0.031 to 0.05.
	When $114.5 \le \theta \le 115.5$	$h/\lambda$ is 0.005 to 0.024 or 0.028 to 0.05.
30	When $115.5 \le \theta \le 155.5$	$h/\lambda$ is 0.005 to 0.05.
	When $155.5 \le \theta \le 156.5$	$h/\lambda$ is 0.0105 to 0.05.
	When $156.5 \le \theta \le 157.5$	$h/\lambda$ is 0.0125 to 0.05.
	When $157.5 \le \theta \le 158.5$	$h/\lambda$ is 0.015 to 0.05.
	When $158.5 \le \theta \le 159.5$	$h/\lambda$ is 0.016 to 0.05.
	When $159.5 \le \theta \le 160.5$	$h/\lambda$ is 0.0175 to 0.05.
35	When $160.5 \le \theta \le 161.5$	$h/\lambda$ is 0.0185 to 0.05.
55	When $161.5 \le \theta \le 162.5$	$h/\lambda$ is 0.0195 to 0.05.
	When $162.5 \le \theta < 163.5$	$h/\lambda$ is 0.0205 to 0.05.
	When $163.5 \le \theta < 164.5$	$h/\lambda$ is 0.021 to 0.05.
	When $164.5 \le \theta < 165.5$	$h/\lambda$ is 0.0215 to 0.05.
	When $165.5 \le \theta < 166.5$	$h/\lambda$ is 0.022 to 0.05.
40	When $166.5 \le \theta < 167.5$	$h/\lambda$ is 0.0225 to 0.05.
40	When $167.5 \le \theta < 168.5$	h/λ is 0.0223 to 0.05.
	When $168.5 \le \theta < 169.5$	h/λ is 0.0235 to 0.05.
	When $169.5 \le \theta < 171.5$	$h/\lambda$ is 0.024 to 0.05.
	When $171.5 \le \theta < 179.5$	$h/\lambda$ is 0.0245 to 0.05.
	When $179.5 \le \theta \le 180$	$h/\lambda$ is 0.024 to 0.05.
45		

		TABLE 25	
50		For $[0.25 \le H/\lambda < 0.35]$	
50	When $0 \le \theta < 0.5$ When $0.5 \le \theta < 3.5$	$h/\lambda$ is 0.0245 to 0.05. $h/\lambda$ is 0.024 to 0.05.	
	When $6.5 \le 0 < 6.5$ When $4.5 \le \theta < 6.5$	h/ $\lambda$ is 0.023 to 0.05. h/ $\lambda$ is 0.023 to 0.05.	
55	When $6.5 \le \theta < 7.5$ When $7.5 \le \theta < 8.5$	h/λ is 0.0225 to 0.05. h/λ is 0.022 to 0.05.	
33	When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$	h/λ is 0.0215 to 0.05. h/λ is 0.021 to 0.05.	
	When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 12.5$	h/λ is 0.0205 to 0.05. h/λ is 0.0195 to 0.05.	
60	When $12.5 \le \theta < 13.5$ When $13.5 \le \theta < 14.5$	$h/\lambda$ is 0.019 to 0.05. $h/\lambda$ is 0.018 to 0.05.	
60	When $14.5 \le \theta \le 15.5$ When $15.5 \le \theta \le 16.5$	$h/\lambda$ is 0.017 to 0.05. $h/\lambda$ is 0.016 to 0.05.	
	When $16.5 \le \theta < 17.5$ When $17.5 \le \theta < 18.5$	$h/\lambda$ is 0.015 to 0.05. $h/\lambda$ is 0.0135 to 0.05.	
	When $18.5 \le \theta < 19.5$ When $19.5 \le \theta < 20.5$	$h/\lambda$ is 0.0115 to 0.05. $h/\lambda$ is 0.0095 to 0.05.	
65	When $20.5 \le \theta < 21.5$ When $21.5 \le \theta < 50.5$	h/ $\lambda$ is 0.006 to 0.05. h/ $\lambda$ is 0.005 to 0.05.	

## 28 TABLE 26-continued

TABLE 25-continued			TABLE 26-continued	
For $[0.25 \le H/\lambda < 0.35]$			F	or $[0.35 \le H/\lambda \le 0.45]$
When $50.5 \le \theta < 51.5$	h/λ is 0.008 to 0.05.	_	When $15.5 \le \theta < 16.5$	h/λ is 0.016 to 0.05.
When $51.5 \le \theta \le 52.5$	$h/\lambda$ is 0.0125 to 0.05.	5	When $16.5 \le \theta \le 17.5$	$h/\lambda$ is 0.015 to 0.05.
When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.015 to 0.05.		When $17.5 \le \theta \le 18.5$	$h/\lambda$ is 0.0135 to 0.05.
When $53.5 \le \theta < 54.5$	$h/\lambda$ is 0.017 to 0.05.		When $18.5 \le \theta < 19.5$	$h/\lambda$ is 0.0125 to 0.05.
When $54.5 \le \theta < 55.5$ When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.018 to 0.05. $h/\lambda$ is 0.019 to 0.05.		When $19.5 \le \theta < 20.5$ When $20.5 \le \theta < 21.5$	$h/\lambda$ is 0.0105 to 0.05. $h/\lambda$ is 0.008 to 0.05.
When $56.5 \le \theta < 57.5$	h/λ is 0.019 to 0.05.		When $21.5 \le \theta < 22.5$	h/λ is 0.0055 to 0.05.
When $57.5 \le \theta < 58.5$	h/λ is 0.021 to 0.05.	10	When $22.5 \le \theta < 49.5$	h/λ is 0.005 to 0.05.
When $58.5 \le \theta < 59.5$	$h/\lambda$ is 0.022 to 0.05.	10	When $49.5 \le \theta \le 50.5$	$h/\lambda$ is 0.0055 to 0.05.
When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.0225 to 0.05.		When $50.5 \le \theta \le 51.5$	$h/\lambda$ is 0.011 to 0.05.
When $60.5 \le \theta \le 61.5$	$h/\lambda$ is 0.023 to 0.05.		When $51.5 \le \theta < 52.5$	$h/\lambda$ is 0.0135 to 0.05.
When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.0235 to 0.05.		When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.0155 to 0.05.
When $62.5 \le \theta < 63.5$ When $63.5 \le \theta < 64.5$	$h/\lambda$ is 0.024 to 0.05.		When $53.5 \le \theta < 54.5$	h/λ is 0.017 to 0.05.
When $64.5 \le \theta < 64.5$ When $64.5 \le \theta < 65.5$	$h/\lambda$ is 0.0245 to 0.05. $h/\lambda$ is 0.025 to 0.05.	15	When $54.5 \le \theta < 55.5$ When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.018 to 0.05. $h/\lambda$ is 0.019 to 0.05.
When $65.5 \le \theta < 66.5$	h/λ is 0.025 to 0.05.		When $56.5 \le \theta < 57.5$	h/λ is 0.02 to 0.05.
When $66.5 \le \theta < 67.5$	$h/\lambda$ is 0.026 to 0.05.		When $57.5 \le \theta < 58.5$	h/λ is 0.0205 to 0.05.
When $67.5 \le \theta \le 68.5$	$h/\lambda$ is 0.0265 to 0.05.		When $58.5 \le \theta < 59.5$	$h/\lambda$ is 0.0215 to 0.05.
When $68.5 \le \theta < 70.5$	$h/\lambda$ is 0.027 to 0.05.		When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.022 to 0.05.
When $70.5 \le \theta \le 71.5$	$h/\lambda$ is 0.0275 to 0.05.	20	When $60.5 \le \theta \le 61.5$	$h/\lambda$ is 0.0225 to 0.05.
When $71.5 \le \theta < 73.5$	$h/\lambda$ is 0.028 to 0.05.	20	When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.023 to 0.05.
When $73.5 \le \theta < 75.5$	$h/\lambda$ is 0.0285 to 0.05.		When $62.5 \le \theta \le 63.5$	$h/\lambda$ is 0.0235 to 0.05.
When $75.5 \le \theta < 77.5$	$h/\lambda$ is 0.029 to 0.05.		When $63.5 \le \theta \le 64.5$	h/λ is 0.024 to 0.05.
When $77.5 \le \theta < 79.5$ When $79.5 \le \theta < 82.5$	h/λ is 0.0295 to 0.05. h/λ is 0.3 to 0.05.		When $64.5 \le \theta < 65.5$ When $65.5 \le \theta < 67.5$	$h/\lambda$ is 0.0245 to 0.05. $h/\lambda$ is 0.025 to 0.05.
When $82.5 \le \theta < 85.5$	h/λ is 0.305 to 0.0.5		When $67.5 \le \theta < 68.5$	h/λ is 0.025 to 0.05.
When $85.5 \le \theta < 89.5$	$h/\lambda$ is 0.031 to 0.05.	25	When $68.5 \le 0 < 69.5$	h/λ is 0.026 to 0.05.
When $89.5 \le \theta \le 102.5$	$h/\lambda$ is 0.0351 to 0.05.		When $69.5 \le \theta < 71.5$	$h/\lambda$ is 0.0265 to 0.05.
When $102.5 \le \theta \le 103.5$	$h/\lambda$ is 0.005 or 0.0315 to 0.05.		When $71.5 \le \theta < 72.5$	$h/\lambda$ is 0.027 to 0.05.
When $103.5 \le \theta \le 104.5$	$h/\lambda$ is 0.005 to 0.006 or 0.0315 to 0.05.		When $72.5 \le \theta < 74.5$	$h/\lambda$ is 0.0275 to 0.05.
When $104.5 \le \theta \le 105.5$	$h/\lambda$ is 0.005 to 0.007 or 0.0315 to 0.05.		When $74.5 \le \theta < 76.5$	$h/\lambda$ is 0.028 to 0.05.
When $105.5 \le \theta < 106.5$	$h/\lambda$ is 0.005 to 0.008 or 0.031 to 0.05.		When $76.5 \le \theta < 79.5$	$h/\lambda$ is 0.0285 to 0.05.
When $106.5 \le \theta \le 107.5$	$h/\lambda$ is 0.005 to 0.009 or 0.031 to 0.05.	30	When $79.5 \le \theta \le 82.5$	h/λ is 0.029 to 0.05.
When $107.5 \le \theta \le 108.5$	h/λ is 0.005 to 0.01 or 0.0305 to 0.05. h/λ is 0.005 to 0.0115 or 0.0305 to 0.05.		When $82.5 \le \theta < 86.5$ When $86.5 \le \theta < 101.5$	h/λ is 0.0295 to 0.05.
When $108.5 \le \theta < 109.5$ When $109.5 \le \theta < 110.5$	h/λ is 0.005 to 0.0115 or 0.0305 to 0.05.		When $101.5 \le \theta < 101.5$ When $101.5 \le \theta < 103.5$	h/ $\lambda$ is 0.03 to 0.05. h/ $\lambda$ is 0.0295 to 0.05.
When $110.5 \le \theta < 111.5$	h/λ is 0.005 to 0.0125 of 0.03 to 0.05.		When $103.5 \le \theta < 104.5$	h/λ is 0.005 or 0.0295 to 0.05.
When $111.5 \le \theta < 112.5$	$h/\lambda$ is 0.005 to 0.016 or 0.028 to 0.05.		When $104.5 \le \theta < 105.5$	$h/\lambda$ is 0.005 to 0.006 or 0.029 to 0.05.
When $112.5 \le \theta \le 113.5$	$h/\lambda$ is 0.005 to 0.0185 or 0.0265 to 0.05.	35	When $105.5 \le \theta < 106.5$	$h/\lambda$ is 0.005 to 0.007 or 0.0285 to 0.05.
When $113.5 \le \theta \le 152.5$	$h/\lambda$ is 0.005 to 0.05.	33	When $106.5 \le \theta \le 107.5$	$h/\lambda$ is 0.005 to 0.0085 or 0.0285 to 0.05.
When $152.5 \le \theta \le 153.5$	$h/\lambda$ is 0.008 to 0.05.		When $107.5 \le \theta \le 108.5$	$h/\lambda$ is 0.005 to 0.0095 or 0.028 to 0.05.
When $153.5 \le \theta < 154.5$	$h/\lambda$ is 0.0105 to 0.05.		When $108.5 \le \theta < 109.5$	$h/\lambda$ is 0.005 to 0.011 or 0.027 to 0.05.
When $154.5 \le \theta < 155.5$	$h/\lambda$ is 0.012 to 0.05.		When $109.5 \le \theta \le 110.5$	$h/\lambda$ is 0.005 to 0.013 or 0.0265 to 0.05.
When $155.5 \le \theta < 156.5$	$h/\lambda$ is 0.035 to 0.05.		When $110.5 \le \theta \le 111.5$	$h/\lambda$ is 0.005 to 0.0145 or 0.0255 to 0.05.
When $156.5 \le \theta < 157.5$	h/λ is 0.015 to 0.05.	40	When $111.5 \le \theta < 112.5$ When $112.5 \le \theta < 151.5$	$h/\lambda$ is 0.005 to 0.019 or 0.0215 to 0.05. $h/\lambda$ is 0.005 to 0.05.
When $157.5 \le \theta < 158.5$ When $158.5 \le \theta < 159.5$	$h/\lambda$ is 0.0165 to 0.05. $h/\lambda$ is 0.0175 to 0.05.		When $151.5 \le \theta < 151.5$ When $151.5 \le \theta < 152.5$	h/λ is 0.0055 to 0.05.
When $159.5 \le \theta < 160.5$	h/λ is 0.018 to 0.05.		When $152.5 \le \theta < 153.5$	h/λ is 0.0075 to 0.05.
When $160.5 \le \theta < 161.5$	h/λ is 0.019 to 0.05.		When $153.5 \le \theta \le 154.5$	$h/\lambda$ is 0.01 to 0.05.
When $161.5 \le \theta < 162.5$	h/λ is 0.02 to 0.05.		When $154.5 \le \theta \le 155.5$	$h/\lambda$ is 0.0115 to 0.0.5
When $162.5 \le \theta < 163.5$	h/λ is 0.0205 to 0.05.		When $155.5 \le \theta \le 156.5$	$h/\lambda$ is 0.013 to 0.05.
When $163.5 \le \theta < 164.5$	$h/\lambda$ is 0.021 to 0.05.	45	When $156.5 \le \theta < 157.5$	$h/\lambda$ is 0.014 to 0.05.
When $164.5 \le \theta < 165.5$	$h/\lambda$ is 0.022 to 0.05.		When $157.5 \le \theta \le 158.5$	$h/\lambda$ is 0.0155 to 0.05.
When $165.5 \le \theta \le 166.5$	$h/\lambda$ is 0.0225 to 0.05.		When $158.5 \le \theta < 159.5$	h/\(\lambda\) is 0.0165 to 0.05.
When $166.5 \le \theta \le 168.5$	$h/\lambda$ is 0.023 to 0.05.		When $159.5 \le \theta < 160.5$ When $160.5 \le \theta < 161.5$	$h/\lambda$ is 0.017 to 0.05. $h/\lambda$ is 0.018 to 0.05.
When $168.5 \le \theta \le 169.5$	$h/\lambda$ is 0.0235 to 0.05.		When $160.5 \le \theta < 161.5$ When $161.5 \le \theta < 162.5$	$h/\lambda$ is 0.018 to 0.03. $h/\lambda$ is 0.018 to 0.05.
When $169.5 \le \theta \le 171.5$	$h/\lambda$ is 0.024 to 0.05.	50	When $162.5 \le \theta < 163.5$	h/λ is 0.018 to 0.05.
When $171.5 \le \theta \le 180$	$h/\lambda$ is 0.0245 to 0.05.		When $163.5 \le \theta < 164.5$	h/λ is 0.02 to 0.05.
		-	When $164.5 \le \theta < 165.5$	h/λ is 0.021 to 0.05.
			When $165.5 \le \theta < 166.5$	h/λ is 0.0215 to 0.05.
			When $166.5 \le \theta < 168.5$	$h/\lambda$ is 0.022 to 0.05.
	TABLE 26		When $168.5 \le \theta < 169.5$	h/λ is 0.0225 to 0.05.
		<b>-</b> 55	When $169.5 \le \theta \le 171.5$	$h/\lambda$ is 0.023 to 0.05.
F	for $[0.35 \le H/\lambda < 0.45]$	_	When $171.5 \le \theta \le 175.5$	$h/\lambda$ is 0.0235 to 0.05.
When $0 \le \theta \le 2.5$	$h/\lambda$ is 0.0235 to 0.05.		When $175.5 \le \theta \le 178.5$	$h/\lambda$ is 0.024 to 0.05.
When $2.5 \le \theta < 4.5$	$h/\lambda$ is 0.023 to 0.05.		When $178.5 \le \theta \le 180$	$h/\lambda$ is 0.0235 to 0.05.
When $4.5 \le \theta \le 5.5$	$h/\lambda$ is 0.0225 to 0.05.		-	
When $5.5 \le \theta < 7.5$	$h/\lambda$ is 0.022 to 0.05.	60		
When $7.5 \le \theta < 8.5$	$h/\lambda$ is 0.0215 to 0.05.	00		
When $8.5 \le \theta \le 9.5$	$h/\lambda$ is 0.021 to 0.05.			TABLE 27
When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.0205 to 0.05.			50 45 XX/2 +0 553
When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 12.5$	$h/\lambda$ is 0.02 to 0.05. $h/\lambda$ is 0.0195 to 0.05.		F	or $[0.45 \le H/\lambda < 0.55]$
When $12.5 \le \theta < 12.5$ When $12.5 \le \theta < 13.5$	h/λ is 0.0193 to 0.03.		When $0 \le \theta \le 2.5$	h/λ is 0.0225 to 0.045.
When $13.5 \le \theta < 14.5$	h/λ is 0.018 to 0.05.	65	When $0.5 \le \theta \le 4.5$	$h/\lambda$ is 0.022 to 0.045.
When $14.5 \le \theta < 15.5$	$h/\lambda$ is 0.017 to 0.05.		When $4.5 \le \theta \le 6.5$	$h/\lambda$ is 0.0215 to 0.045.

When  $0 \le \theta < 0.5$ When  $0.5 \le \theta < 3.5$ When  $3.5 \le \theta < 5.5$ 

When  $5.5 \le \theta < 6.5$ When  $6.5 \le \theta < 7.5$   $h/\lambda$  is 0.022 to 0.045.  $h/\lambda$  is 0.0215 to 0.045.

 $h/\lambda$  is 0.021 to 0.045.

 $h/\lambda$  is 0.0205 to 0.045.  $h/\lambda$  is 0.02 to 0.045.

30
TABLE 28-continued

TABLE 27	7-continued		TABLE 28	3-continued
For [0.45 ≤	$H/\lambda < 0.55$ ]		For [0.55 ≤	$H/\lambda < 0.65$ ]
When $6.5 \le \theta < 7.5$	h/λ is 0.021 to 0.045.		When $7.5 \le \theta < 9.5$	h/λ is 0.0195 to 0.045.
When $7.5 \le \theta \le 8.5$	$h/\lambda$ is 0.0205 to 0.045.	5	When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.019 to 0.045.
When $8.5 \le \theta < 9.5$	$h/\lambda$ is 0.02 to 0.045.		When $10.5 \le \theta \le 11.5$	$h/\lambda$ is 0.0185 to 0.045.
When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.0195 to 0.045.		When $11.5 \le \theta \le 12.5$	$h/\lambda$ is 0.0175 to 0.045.
When $10.5 \le \theta < 11.5$	$h/\lambda$ is 0.019 to 0.045.		When $12.5 \le \theta < 13.5$	$h/\lambda$ is 0.017 to 0.045.
When $11.5 \le \theta < 12.5$	$h/\lambda$ is 0.0185 to 0.045.		When $13.5 \le \theta < 14.5$	$h/\lambda$ is 0.0165 to 0.045.
When $12.5 \le \theta < 13.5$	$h/\lambda$ is 0.018 to 0.045.		When $14.5 \le \theta < 15.5$	$h/\lambda$ is 0.0155 to 0.045.
When $13.5 \le \theta < 14.5$	h/λ is 0.017 to 0.045.	10	When $15.5 \le \theta < 16.5$	$h/\lambda$ is 0.0145 to 0.045.
When $14.5 \le \theta \le 15.5$	$h/\lambda$ is 0.0165 to 0.045.		When $16.5 \le \theta < 17.5$	$h/\lambda$ is 0.0135 to 0.045.
When $15.5 \le \theta \le 16.5$	$h/\lambda$ is 0.0155 to 0.045.		When $17.5 \le \theta \le 18.5$	$h/\lambda$ is 0.012 to 0.045.
When $16.5 \le \theta < 17.5$ When $17.5 \le \theta < 18.5$	$h/\lambda$ is 0.0145 to 0.045. $h/\lambda$ is 0.013 to 0.045.		When $18.5 \le \theta < 19.5$ When $19.5 \le \theta < 20.5$	h/λ is 0.011 to 0.045. h/λ is 0.009 to 0.045.
When $17.5 \le 0 < 18.5$ When $18.5 \le \theta < 19.5$	$h/\lambda$ is 0.013 to 0.043.		When $20.5 \le \theta < 20.5$ When $20.5 \le \theta < 21.5$	h/λ is 0.0065 to 0.045.
When $19.5 \le \theta < 19.5$ When $19.5 \le \theta < 20.5$	h/λ is 0.0113 to 0.045.		When $20.5 \le \theta < 21.5$ When $21.5 \le \theta < 50.5$	$h/\lambda$ is 0.0005 to 0.045.
When $20.5 \le \theta < 20.5$ When $20.5 \le \theta < 21.5$	h/λ is 0.008 to 0.045.	15	When $50.5 \le \theta < 51.5$	$h/\lambda$ is 0.0085 to 0.045.
When $21.5 \le \theta < 50.5$	h/λ is 0.005 to 0.045.		When $51.5 \le 0 < 51.5$ When $51.5 \le 0 < 52.5$	h/λ is 0.0115 to 0.045.
When $50.5 \le 0 < 51.5$	h/λ is 0.0105 to 0.045.		When $52.5 \le 0 \le 52.5$	$h/\lambda$ is 0.0135 to 0.045.
When $51.5 \le 0 < 52.5$	$h/\lambda$ is 0.013 to 0.045.		When $53.5 \le 0 < 54.5$	$h/\lambda$ is 0.0155 to 0.045.
When $52.5 \le 0 \le 53.5$	$h/\lambda$ is 0.015 to 0.045.		When $54.5 \le 0 < 55.5$	$h/\lambda$ is 0.0165 to 0.045.
When $53.5 \le 0 < 54.5$	$h/\lambda$ is 0.016 to 0.045.		When $55.5 \le \theta \le 56.5$	$h/\lambda$ is 0.0175 to 0.045.
When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.0175 to 0.045.	20	When $56.5 \le \theta < 57.5$	$h/\lambda$ is 0.0185 to 0.045.
When $55.5 \le \theta \le 56.5$	$h/\lambda$ is 0.0185 to 0.045.		When $57.5 [M4] \le \theta < 58.5$	$h/\lambda$ is 0.019 to 0.045.
When $56.5 \le \theta \le 57.5$	$h/\lambda$ is 0.019 to 0.045.		When $58.5 \le \theta \le 59.5$	$h/\lambda$ is 0.02 to 0.045.
When $57.5 \le \theta \le 58.5$	$h/\lambda$ is 0.02 to 0.045.		When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.0205 to 0.045.
When $58.5 \le \theta < 59.5$	$h/\lambda$ is 0.0205 to 0.045.		When $60.5 \le \theta \le 61.5$	$h/\lambda$ is 0.021 to 0.045.
When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.0215 to 0.045.		When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.0215 to 0.045.
When $60.5 \le \theta \le 61.5$	$h/\lambda$ is 0.022 to 0.045.	25	When $62.5 \le \theta \le 63.5$	$h/\lambda$ is 0.022 to 0.045.
When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.0225 to 0.045.		When $63.5 \le \theta \le 64.5$	$h/\lambda$ is 0.0225 to 0.045.
When $62.5 \le \theta \le 63.5$	$h/\lambda$ is 0.023 to 0.045.		When $64.5 \le \theta \le 65.5$	$h/\lambda$ is 0.023 to 0.045.
When $63.5 \le \theta < 65.5$	$h/\lambda$ is 0.0235 to 0.045.		When $65.5 \le \theta < 67.5$	$h/\lambda$ is 0.0235 to 0.045.
When $65.5 \le \theta \le 66.5$	$h/\lambda$ is 0.024 to 0.045.		When $67.5 \le \theta \le 68.5$	$h/\lambda$ is 0.024 to 0.045.
When $66.5 \le \theta \le 67.5$	$h/\lambda$ is 0.0245 to 0.045.		When $68.5 \le \theta < 70.5$	$h/\lambda$ is 0.0245 to 0.045.
When $67.5 \le \theta \le 69.5$	$h/\lambda$ is 0.025 to 0.045.	30	When $70.5 \le \theta < 72.5$	$h/\lambda$ is 0.025 to 0.045.
When $69.5 \le \theta < 70.5$	$h/\lambda$ is 0.0255 to 0.045.		When $72.5 \le \theta < 73.5$	$h/\lambda$ is 0.0255 to 0.045.
When $70.5 \le \theta < 72.5$	$h/\lambda$ is 0.026 to 0.045.		When $73.5 \le \theta < 75.5$	$h/\lambda$ is 0.026 to 0.045.
When $72.5 \le \theta < 74.5$	$h/\lambda$ is 0.0265 to 0.045.		When $75.5 \le \theta < 78.5$	$h/\lambda$ is 0.0265 to 0.045.
When $74.5 \le \theta < 76.5$	$h/\lambda$ is 0.027 to 0.045.		When $78.5 \le \theta < 81.5$	$h/\lambda$ is 0.027 to 0.045.
When $76.5 \le \theta < 79.5$	$h/\lambda$ is 0.0275 to 0.045.		When $81.5 \le \theta < 85.5$	$h/\lambda$ is 0.0275 to 0.045.
When $79.5 \le \theta < 82.5$	$h/\lambda$ is 0.028 to 0.045.	35	When $85.5 \le \theta < 95.5$	$h/\lambda$ is 0.028 to 0.045.
When $82.5 \le \theta < 87.5$	$h/\lambda$ is 0.0285 to 0.045.		When $95.5 \le \theta < 98.5$	$h/\lambda$ is 0.0275 to 0.045.
When $87.5 \le \theta < 96.5$	$h/\lambda$ is 0.029 to 0.045.		When $98.5 \le \theta < 101.5$	$h/\lambda$ is 0.027 to 0.045.
When $96.5 \le \theta < 100.5$	$h/\lambda$ is 0.0285 to 0.045.		When $101.5 \le \theta < 102.5$	$h/\lambda$ is 0.0265 to 0.045.
When $100.5 \le \theta < 102.5$	$h/\lambda$ is 0.028 to 0.045.		When $102.5 \le \theta < 103.5$	$h/\lambda$ is 0.026 to 0.045.
When $102.5 \le \theta < 103.5$ When $103.5 \le \theta < 153.5$	$h/\lambda$ is 0.0275 to 0.045.		When $103.5 \le \theta < 154.5$ When $154.5 \le \theta < 155.5$	h/λ is 0.005 to 0.045. h/λ is 0.0055 to 0.045.
When $103.5 \le \theta < 133.5$ When $153.5 \le \theta < 154.5$	h/λ is 0.05 to 0.045.	40		
When $154.5 \le \theta < 154.5$ When $154.5 \le \theta < 155.5$	$h/\lambda$ is 0.075 to 0.045. $h/\lambda$ is 0.095 to 0.045.		When $155.5 \le \theta < 156.5$ When $156.5 \le \theta < 157.5$	h/λ is 0.008 to 0.045. h/λ is 0.01 to 0.045.
When $154.5 \le 0 < 155.5$ When $155.5 \le \theta < 156.5$	$h/\lambda$ is 0.043.		When $150.5 \le \theta < 157.5$ When $157.5 \le \theta < 158.5$	$h/\lambda$ is 0.0115 to 0.045.
When $156.5 \le \theta < 157.5$	h/λ is 0.0125 to 0.045.		When $157.5 \le 0 < 158.5$ When $158.5 \le 0 < 159.5$	$h/\lambda$ is 0.0115 to 0.045.
When $157.5 \le \theta < 158.5$	h/λ is 0.0125 to 0.045.		When $158.5 \le 0 < 159.5$ When $159.5 \le 0 < 160.5$	$h/\lambda$ is 0.0123 to 0.043.
When $157.5 \le \theta < 158.5$ When $158.5 \le \theta < 159.5$	h/λ is 0.0145 to 0.045.		When $160.5 \le \theta < 160.5$ When $160.5 \le \theta < 161.5$	$h/\lambda$ is 0.014 to 0.045.
When $159.5 \le 0 < 159.5$ When $159.5 \le \theta < 160.5$	$h/\lambda$ is 0.0145 to 0.045.	45	When $161.5 \le \theta < 162.5$	$h/\lambda$ is 0.013 to 0.043.
When $160.5 \le \theta < 161.5$	$h/\lambda$ is 0.0165 to 0.045.			$h/\lambda$ is 0.016 to 0.045.
When $161.5 \le \theta < 162.5$	$h/\lambda$ is 0.0175 to 0.045.		When $162.5 \le \theta \le 163.5$ When $163.5 \le \theta \le 164.5$	
When $162.5 \le \theta < 163.5$	h/λ is 0.0175 to 0.045.			h/λ is 0.0175 to 0.045.
When $163.5 \le \theta < 164.5$	$h/\lambda$ is 0.019 to 0.045.		When $164.5 \le \theta < 165.5$	$h/\lambda$ is 0.018 to 0.045.
When $164.5 \le \theta < 165.5$	$h/\lambda$ is 0.019 to 0.045.		When $165.5 \le \theta < 166.5$	$h/\lambda$ is 0.0185 to 0.045.
		50	When $166.5 \le \theta < 168.5$	$h/\lambda$ is 0.0195 to 0.045.
When $165.5 \le \theta \le 166.5$	h/λ is 0.02 to 0.045.		When $168.5 \le \theta < 169.5$	$h/\lambda$ is 0.02 to 0.045.
When $166.5 \le \theta < 167.5$	h/λ is 0.0205 to 0.045.		When $169.5 \le \theta < 170.5$	$h/\lambda$ is 0.0205 to 0.045.
When $167.5 \le \theta \le 168.5$	$h/\lambda$ is 0.021 to 0.045.		When $171.5 \le \theta < 172.5$	$h/\lambda$ is 0.021 to 0.045.
When $168.5 \le \theta < 170.5$	$h/\lambda$ is 0.0215 to 0.045.		When $172.5 \le \theta < 175.5$	$h/\lambda$ is 0.0215 to 0.045.
When $170.5 \le \theta < 172.5$	$h/\lambda$ is 0.022 to 0.045.		When $175.5 \le \theta \le 180$	$h/\lambda$ is 0.022 to 0.045.
When $172.5 \le \theta < 175.5$	$h/\lambda$ is 0.0225 to 0.045.	55		
When $175.5 \le \theta < 179.5$ When $179.5 \le \theta < 180$	h/λ is 0.023 to 0.045. h/λ is 0.0225 to 0.045.			
			TAB	LE <b>2</b> 9
ТАВ	LE <b>2</b> 8	_	For [0.65 ≤	$H/\lambda < 0.75$ ]
		60	When $0 \le \theta \le 1.5$	$h/\lambda$ is 0.021 to 0.045.
For [0.55 ≤	$H/\lambda < 0.65$		When $1.5 \le \theta < 4.5$	h/λ is 0.0205 to 0.045.

When  $4.5 \le \theta \le 5.5$ 

When  $4.5 \le \theta < 3.5$ When  $5.5 \le \theta < 7.5$ When  $7.5 \le \theta < 8.5$ When  $8.5 \le \theta < 9.5$ When  $9.5 \le \theta < 10.5$ When  $10.5 \le \theta < 11.5$ 

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 $h/\lambda$  is 0.02 to 0.045.

 $h/\lambda$  is 0.0195 to 0.045.  $h/\lambda$  is 0.019 to 0.045.

h/ $\lambda$  is 0.018 to 0.045. h/ $\lambda$  is 0.018 to 0.045. h/ $\lambda$  is 0.0175 to 0.045.

TABLE 29-continued

## 32 TABLE 30-continued

TABLE	E 29-continued		TABLE 30	)-continued
For [0.	For $[0.65 \le H/\lambda < 0.75]$		For [0.75 ≤	$H/\lambda < 0.85$ ]
When $11.5 \le \theta \le 12.5$	h/λ is 0.017 to 0.045.		When $19.5 \le \theta \le 20.5$	h/λ is 0.0065 to 0.045.
When $12.5 \le \theta \le 13.5$	$h/\lambda$ is 0.016 to 0.045.	5	When $20.5 \le \theta < 51.5$	$h/\lambda$ is 0.005 to 0.045.
When $13.5 \le \theta \le 14.5$	$h/\lambda$ is 0.0155 to 0.045.		When $51.5 \le \theta \le 52.5$	$h/\lambda$ is 0.0085 to 0.045.
When $14.5 \le \theta < 15.5$	$h/\lambda$ is 0.0145 to 0.045.		When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.0115 to 0.045.
When $15.5 \le \theta < 16.5$	$h/\lambda$ is 0.0135 to 0.045.		When $53.5 \le \theta < 54.5$	$h/\lambda$ is 0.013 to 0.045.
When $16.5 \le \theta < 17.5$	$h/\lambda$ is 0.0125 to 0.045.		When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.0145 to 0.045.
When $17.5 \le 0 < 18.5$	h/λ is 0.0115 to 0.045.		When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.016 to 0.045.
When $18.5 \le \theta < 19.5$ When $19.5 \le \theta < 20.5$	$h/\lambda$ is 0.0095 to 0.045. $h/\lambda$ is 0.0075 to 0.045.	10	When $56.5 \le \theta < 57.5$ When $57.5 \le \theta < 58.5$	h/λ is 0.017 to 0.045. h/λ is 0.0175 to 0.045.
When $20.5 \le \theta < 20.5$ When $20.5 \le \theta < 21.5$	h/λ is 0.0075 to 0.045.		When $57.5 \le 0 < 58.5$ When $58.5 \le \theta < 59.5$	h/λ is 0.0185 to 0.045.
When $21.5 \le \theta < 50.5$	$h/\lambda$ is 0.005 to 0.045.		When $59.5 \le \theta < 60.5$	$h/\lambda$ is 0.019 to 0.045.
When $50.5 \le \theta < 51.5$	$h/\lambda$ is 0.0065 to 0.045.		When $60.5 \le \theta < 61.5$	$h/\lambda$ is 0.0195 to 0.045.
When $51.5 \le \theta \le 52.5$	$h/\lambda$ is 0.0105 to 0.045.		When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.0205 to 0.045.
When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.0125 to 0.045.	15	When $62.5 \le \theta < 63.5$	$h/\lambda$ is 0.021 to 0.045.
When $53.5 \le \theta \le 54.5$	$h/\lambda$ is 0.014 to 0.045.	13	When $63.5 \le \theta \le 65.5$	$h/\lambda$ is 0.0215 to 0.045.
When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.0155 to 0.045.		When $65.5 \le \theta \le 66.5$	$h/\lambda$ is 0.022 to 0.045.
When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.0165 to 0.045.		When $66.5 \le \theta < 67.5$	$h/\lambda$ is 0.0225 to 0.045.
When $56.5 \le \theta < 57.5$	$h/\lambda$ is 0.0175 to 0.045.		When $67.5 \le \theta < 68.5$	$h/\lambda$ is 0.023 to 0.045.
When $57.5 \le \theta < 58.5$	$h/\lambda$ is 0.0185 to 0.045.		When $68.5 \le \theta < 70.5$	$h/\lambda$ is 0.0235 to 0.045.
When $58.5 \le 0 < 59.5$	$h/\lambda$ is 0.019 to 0.045.	20	When $70.5 \le \theta < 72.5$	$h/\lambda$ is 0.024 to 0.045.
When $59.5 \le \theta < 60.5$ When $60.5 \le \theta < 61.5$	h/ $\lambda$ is 0.0195 to 0.045. h/ $\lambda$ is 0.0205 to 0.045.		When $72.5 \le \theta < 74.5$ When $74.5 \le \theta < 76.5$	h/λ is 0.0245 to 0.045. h/λ is 0.025 to 0.045.
When $60.5 \le 0 < 61.5$ When $61.5 \le 0 < 62.5$	$h/\lambda$ is 0.0203 to 0.043.		When $74.5 \le 0 < 76.5$ When $76.5 \le \theta < 79.5$	$h/\lambda$ is 0.025 to 0.045.
When $62.5 \le 0 < 62.5$ When $62.5 \le 0 < 63.5$	$h/\lambda$ is 0.021 to 0.045.		When $70.5 \le 0 < 75.5$ When $79.5 \le \theta < 83.5$	h/λ is 0.026 to 0.045.
When $63.5 \le \theta < 64.5$	$h/\lambda$ is 0.022 to 0.045.		When $83.5 \le 0 < 96.5$	$h/\lambda$ is 0.0265 to 0.045.
When $64.5 \le \theta < 66.5$	$h/\lambda$ is 0.0225 to 0.045.		When $96.5 \le \theta < 98.5$	$h/\lambda$ is 0.026 to 0.045.
When $66.5 \le \theta \le 67.5$	$h/\lambda$ is 0.023 to 0.045.	25	When $98.5 \le \theta < 99.5$	$h/\lambda$ is 0.025 to 0.045.
When $67.5 \le \theta \le 68.5$	$h/\lambda$ is 0.0235 to 0.045.		When $99.5 \le \theta \le 100.5$	$h/\lambda$ is 0.0245 to 0.045.
When $68.5 \le \theta < 70.5$	$h/\lambda$ is 0.024 to 0.045.		When $100.5 \le \theta \le 159.5$	$h/\lambda$ is 0.005 to 0.045.
When $70.5 \le \theta < 72.5$	$h/\lambda$ is 0.0245 to 0.045.		When $159.5 \le \theta \le 160.5$	$h/\lambda$ is 0.0055 to 0.045.
When $72.5 \le \theta < 74.5$	$h/\lambda$ is 0.025 to 0.045.		When $160.5 \le \theta \le 161.5$	$h/\lambda$ is 0.009 to 0.045.
When $74.5 \le \theta < 76.5$	$h/\lambda$ is 0.0255 to 0.045.		When $161.5 \le \theta \le 162.5$	$h/\lambda$ is 0.011 to 0.045.
When $76.5 \le \theta < 79.5$	$h/\lambda$ is 0.026 to 0.045.	30	When $162.5 \le \theta \le 163.5$	$h/\lambda$ is 0.0125 to 0.045.
When $79.5 \le \theta < 82.5$	$h/\lambda$ is 0.0265 to 0.045.		When $163.5 \le \theta \le 164.5$	$h/\lambda$ is 0.014 to 0.045.
When $82.5 \le \theta < 95.5$	$h/\lambda$ is 0.027 to 0.045.		When $164.5 \le \theta \le 165.5$	$h/\lambda$ is 0.015 to 0.045.
When $95.5 \le 0 < 98.5$	h/λ is 0.0265 to 0.045.		When $165.5 \le \theta \le 166.5$	$h/\lambda$ is 0.016 to 0.045.
When $98.5 \le \theta < 100.5$	h/λ is 0.026 to 0.045.		When $166.5 \le \theta \le 167.5$	$h/\lambda$ is 0.0165 to 0.045.
When $100.5 \le \theta < 101.5$ When $101.5 \le \theta < 157.5$	$h/\lambda$ is 0.0255 to 0.045. $h/\lambda$ is 0.005 to 0.045.		When $167.5 \le \theta \le 168.5$	$h/\lambda$ is 0.017 to 0.045.
When $157.5 \le \theta < 157.5$ When $157.5 \le \theta < 158.5$	h/λ is 0.003 to 0.043.	35	When $168.5 \le \theta \le 169.5$	$h/\lambda$ is 0.018 to 0.045.
When $158.5 \le \theta < 159.5$	h/λ is 0.01 to 0.045.		When $169.5 \le \theta \le 171.5$	$h/\lambda$ is 0.0185 to 0.045.
When $159.5 \le \theta < 160.5$	$h/\lambda$ is 0.0115 to 0.045.		When $171.5 \le \theta \le 172.5$	$h/\lambda$ is 0.019 to 0.045.
When $160.5 \le \theta < 161.5$	$h/\lambda$ is 0.0125 to 0.045.		When $172.5 \le \theta \le 174.5$	$h/\lambda$ is 0.0195 to 0.045.
When $161.5 \le \theta < 162.5$	$h/\lambda$ is 0.014 to 0.045.		When $174.5 \le \theta \le 180$	$h/\lambda$ is 0.02 to 0.045.
When $162.5 \le \theta < 163.5$	$h/\lambda$ is 0.015 to 0.045.			
When $163.5 \le \theta \le 164.5$	$h/\lambda$ is 0.016 to 0.045.	40		
When $164.5 \le \theta \le 165.5$	$h/\lambda$ is 0.0165 to 0.045.			
When $165.5 \le \theta \le 166.5$	$h/\lambda$ is 0.0175 to 0.045.		TAB	LE 31
When $166.5 \le \theta \le 167.5$	$h/\lambda$ is 0.018 to 0.045.	_		
When $167.5 \le \theta \le 168.5$	$h/\lambda$ is 0.0185 to 0.045.		For [0.85 ≤	$H/\lambda < 0.95$
When $168.5 \le \theta \le 169.5$	$h/\lambda$ is 0.019 to 0.045.	45	WII 0 0 2 5	1.0 1.0 0105 ( 0.045
When $169.5 \le \theta < 170.5$	$h/\lambda$ is 0.0195 to 0.045.	43	When $0 \le \theta < 2.5$	$h/\lambda$ is 0.0195 to 0.045.
When $170.5 \le \theta \le 172.5$	$h/\lambda$ is 0.02 to 0.045.		When $2.5 \le \theta < 4.5$ When $4.5 \le \theta < 6.5$	h/λ is 0.019 to 0.045. h/λ is 0.0185 to 0.045.
When $172.5 \le \theta \le 175.5$	$h/\lambda$ is 0.0205 to 0.045.		When $6.5 \le 0 < 0.5$ When $6.5 \le 0 < 7.5$	h/λ is 0.018 to 0.045.
When $175.5 \le \theta \le 180$	$h/\lambda$ is 0.021 to 0.045.		When $7.5 \le \theta < 9.5$	$h/\lambda$ is 0.0175 to 0.045.
			When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.017 to 0.045.
		50	When $10.5 \le \theta < 11.5$	$h/\lambda$ is 0.016 to 0.045.
			When $11.5 \le \theta \le 12.5$	$h/\lambda$ is 0.0155 to 0.045.
T	ABLE 30		When $12.5 \le \theta < 13.5$	$h/\lambda$ is 0.015 to 0.045.
			When $13.5 \le \theta \le 14.5$	$h/\lambda$ is 0.014 to 0.045.
For [0.	$75 \le H/\lambda < 0.85$		When $14.5 \le \theta \le 15.5$	$h/\lambda$ is 0.013 to 0.045.
			When $15.5 \le \theta < 16.5$	$h/\lambda$ is 0.012 to 0.045.
When $0 \le \theta < 3.5$	$h/\lambda$ is 0.02 to 0.045.	55	When $16.5 \le \theta < 17.5$	$h/\lambda$ is 0.011 to 0.045.
When $3.5 \le \theta < 5.5$	$h/\lambda$ is 0.0195 to 0.045.		When $17.5 \le \theta < 18.5$	$h/\lambda$ is 0.009 to 0.045.
When $5.5 \le \theta \le 6.5$ When $6.5 \le \theta \le 8.5$	$h/\lambda$ is 0.019 to 0.045.		When $18.5 \le \theta \le 19.5$ When $19.5 \le \theta \le 51.5$	$h/\lambda$ is 0.007 to 0.045.
When $6.5 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$	$h/\lambda$ is 0.0185 to 0.045. $h/\lambda$ is 0.018 to 0.045.		When $19.5 \le \theta < 51.5$ When $51.5 \le \theta < 52.5$	h/λ is 0.007 to 0.045. h/λ is 0.0065 to 0.045.
When $9.5 \le \theta < 9.3$ When $9.5 \le \theta < 10.5$	$h/\lambda$ is 0.018 to 0.043. $h/\lambda$ is 0.0175 to 0.045.		When $52.5 \le \theta < 52.5$ When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.0063 to 0.043. $h/\lambda$ is 0.0105 to 0.045.
When $9.5 \le 0 < 10.5$ When $10.5 \le \theta < 11.5$	$h/\lambda$ is 0.0173 to 0.043.		When $52.5 \le \theta < 53.5$ When $53.5 \le \theta < 54.5$	$h/\lambda$ is 0.0103 to 0.043.
When $11.5 \le \theta < 12.5$	$h/\lambda$ is 0.016 to 0.045.	60	When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.014 to 0.045.
When $12.5 \le \theta < 13.5$	$h/\lambda$ is 0.0155 to 0.045.		When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.015 to 0.045.
When $13.5 \le \theta < 14.5$	$h/\lambda$ is 0.0145 to 0.045.		When $56.5 \le \theta < 57.5$	$h/\lambda$ is 0.016 to 0.045.
When $14.5 \le \theta \le 15.5$	$h/\lambda$ is 0.014 to 0.045.		When $57.5 \le \theta < 58.5$	$h/\lambda$ is 0.017 to 0.045.
When $15.5 \le \theta \le 16.5$	$h/\lambda$ is 0.013 to 0.045.		When $58.5 \le \theta \le 59.5$	$h/\lambda$ is 0.018 to 0.045.
When $16.5 \le \theta \le 17.5$	$h/\lambda$ is 0.0115 to 0.045.		When $59.5 \le \theta \le 60.5$	$h/\lambda$ is 0.0185 to 0.045.
When $17.5 \le \theta < 18.5$	$h/\lambda$ is 0.0105 to 0.045.	65	When $60.5 \le \theta < 61.5$	$h/\lambda$ is 0.019 to 0.045.
When $18.5 \le \theta < 19.5$	$h/\lambda$ is 0.0085 to 0.045.		When $61.5 \le \theta \le 62.5$	$h/\lambda$ is 0.02 to 0.045.

TABLE 31-continued

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TABLE 32-continued

For $[0.85 \le H/\lambda < 0.95]$		
When $62.5 \le \theta \le 63.5$	h/λ is 0.0205 to 0.045.	
When $63.5 \le \theta < 64.5$	$h/\lambda$ is 0.021 to 0.045.	
When $64.5 \le \theta < 65.5$	$h/\lambda$ is 0.0215 to 0.045.	
When $65.5 \le \theta < 66.5$	$h/\lambda$ is 0.022 to 0.045.	
When $66.5 \le \theta < 68.5$	$h/\lambda$ is 0.0225 to 0.045.	
When $68.5 \le \theta < 70.5$	$h/\lambda$ is 0.023 to 0.045.	
When $70.5 \le \theta < 72.5$	$h/\lambda$ is 0.0235 to 0.045.	
When $72.5 \le \theta < 74.5$	$h/\lambda$ is 0.024 to 0.045.	
When $74.5 \le \theta < 76.5$	$h/\lambda$ is 0.0245 to 0.045.	
When $76.5 \le \theta < 79.5$	$h/\lambda$ is 0.025 to 0.045.	
When $79.5 \le \theta < 82.5$	$h/\lambda$ is 0.0255 to 0.045.	
When $82.5 \le \theta < 92.5$	$h/\lambda$ is 0.026 to 0.045.	
When $92.5 \le \theta < 95.5$	$h/\lambda$ is 0.0255 to 0.045.	
When $95.5 \le \theta < 97.5$	$h/\lambda$ is 0.025 to 0.045.	
When $97.5 \le \theta < 98.5$	$h/\lambda$ is 0.0245 to 0.045.	
When $98.5 \le \theta < 163.5$	$h/\lambda$ is 0.05 to 0.045.	
When $163.5 \le \theta \le 164.5$	$h/\lambda$ is 0.0105 to 0.045.	
When $164.5 \le \theta < 165.5$	$h/\lambda$ is 0.012 to 0.045.	
When $165.5 \le \theta < 166.5$	$h/\lambda$ is 0.0135 to 0.045.	
When $166.5 \le \theta \le 167.5$	$h/\lambda$ is 0.015 to 0.045.	
When $167.5 \le \theta \le 168.5$	$h/\lambda$ is 0.016 to 0.045.	
When $168.5 \le \theta \le 169.5$	$h/\lambda$ is 0.0165 to 0.045.	
When $169.5 \le \theta \le 170.5$	$h/\lambda$ is 0.017 to 0.045.	
When $170.5 \le \theta \le 171.5$	$h/\lambda$ is 0.0175 to 0.045.	
When $171.5 \le \theta \le 172.5$	$h/\lambda$ is 0.018 to 0.045.	
When $172.5 \le \theta \le 174.5$	$h/\lambda$ is 0.0185 to 0.045.	
When $174.5 \le 0 \le 176.5$	$h/\lambda$ is 0.019 to 0.045.	
When $174.5 \le 0 < 176.5$ When $176.5 \le 0 < 180$	h/λ is 0.0195 to 0.045.	
# Hell 170.5 ≤ 0 < 100	II N IS 0.0123 to 0.043.	

### TABLE 32

For [0.95	$5 \le H/\lambda \le 1.00$
When $0 \le \theta < 1.5$ When $1.5 \le \theta < 4.5$	h/λ is 0.019 to 0.04. h/λ is 0.0185 to 0.04.
When $4.5 \le \theta < 6.5$	$h/\lambda$ is 0.018 to 0.04.
When $6.5 \le \theta < 7.5$	$h/\lambda$ is 0.0175 to 0.04.
When $7.5 \le \theta \le 8.5$	$h/\lambda$ is 0.017 to 0.04.
When $8.5 \le \theta < 9.5$	$h/\lambda$ is 0.0165 to 0.04.
When $9.5 \le \theta \le 10.5$	$h/\lambda$ is 0.016 to 0.04.
When $10.5 \le \theta \le 11.5$	$h/\lambda$ is 0.0155 to 0.04.
When $11.5 \le \theta \le 12.5$	$h/\lambda$ is 0.015 to 0.04.
When $12.5 \le \theta \le 13.5$	$h/\lambda$ is 0.014 to 0.04.
When $13.5 \le \theta \le 14.5$	$h/\lambda$ is 0.0135 to 0.04.
When $14.5 \le \theta \le 15.5$	$h/\lambda$ is 0.0125 to 0.04.
When $15.5 \le \theta \le 16.5$	$h/\lambda$ is 0.0115 to 0.04.
When $16.5 \le \theta \le 17.5$	$h/\lambda$ is 0.01 to 0.04.
When $17.5 \le \theta \le 18.5$	$h/\lambda$ is 0.008 to 0.04.
When $18.5 \le \theta < 19.5$	$h/\lambda$ is 0.006 to 0.04.
When $19.5 \le \theta \le 52.5$	$h/\lambda$ is 0.005 to 0.04.
When $52.5 \le \theta < 53.5$	$h/\lambda$ is 0.009 to 0.04.
When $53.5 \le \theta < 54.5$	$h/\lambda$ is 0.0115 to 0.04.
When $54.5 \le \theta < 55.5$	$h/\lambda$ is 0.013 to 0.04.
When $55.5 \le \theta < 56.5$	$h/\lambda$ is 0.0145 to 0.04.
When $56.5 \le \theta < 57.5$	$h/\lambda$ is 0.0155 to 0.04.
When $57.5 \le \theta < 58.5$	$h/\lambda$ is 0.0165 to 0.04.
When $58.5 \le \theta < 59.5$	$h/\lambda$ is 0.0175 to 0.04.
When $59.5 \le \theta < 60.5$	$h/\lambda$ is 0.018 to 0.04.
When $60.5 \le \theta < 61.5$	$h/\lambda$ is 0.019 to 0.04.
When $61.5 \le \theta < 62.5$	$h/\lambda$ is 0.0195 to 0.04.
When $62.5 \le \theta < 63.5$	$h/\lambda$ is 0.02 to 0.04.
When $63.5 \le \theta < 64.5$	$h/\lambda$ is 0.0205 to 0.04.
When $64.5 \le \theta < 65.5$	$h/\lambda$ is 0.021 to 0.04.
When $65.5 \le \theta < 66.5$	$h/\lambda$ is 0.0215 to 0.04.
When $66.5 \le \theta < 68.5$	$h/\lambda$ is 0.022 to 0.04.
When $68.5 \le \theta < 69.5$	$h/\lambda$ is 0.0225 to 0.04.
When $69.5 \le \theta < 71.5$	$h/\lambda$ is 0.023 to 0.04.
When $71.5 \le \theta < 73.5$	$h/\lambda$ is 0.0235 to 0.04.
When $73.5 \le \theta < 75.5$	$h/\lambda$ is 0.024 to 0.04.
When $75.5 \le \theta < 78.5$	$h/\lambda$ is 0.0245 to 0.04.
When $78.5 \le \theta < 81.5$	$h/\lambda$ is 0.025 to 0.04.
When $81.5 \le \theta < 92.5$	$h/\lambda$ is 0.0255 to 0.04.
When $92.5 \le \theta < 94.5$	$h/\lambda$ is 0.025 to 0.04.
When $94.5 \le \theta < 95.5$	$h/\lambda$ is 0.0245 to 0.04.
When $95.5 \le \theta \le 166.5$	$h/\lambda$ is 0.005 to 0.04.

	For [0.95 ≤	H/λ < 1.00 J	
	When $166.5 \le \theta \le 167.5$	$h/\lambda$ is 0.0115 to 0.04.	
5	When $167.5 \le \theta \le 168.5$	$h/\lambda$ is 0.0135 to 0.04.	
	When $168.5 \le \theta \le 169.5$	$h/\lambda$ is 0.015 to 0.04.	
	When $169.5 \le \theta \le 170.5$	$h/\lambda$ is 0.0155 to 0.04.	
	When $170.5 \le \theta \le 171.5$	$h/\lambda$ is 0.0165 to 0.04.	
	When $171.5 \le \theta \le 172.5$	$h/\lambda$ is 0.017 to 0.04.	
	When $172.5 \le \theta \le 173.5$	$h/\lambda$ is 0.0175 to 0.04.	
10	When $173.5 \le \theta < 175.5$	$h/\lambda$ is 0.018 to 0.04.	
	When $175.5 \le \theta < 178.5$	$h/\lambda$ is 0.0185 to 0.04.	
	When $178.5 \le \theta \le 180$	$h/\lambda$ is 0.019 to 0.04.	

The results shown in FIGS. 20 to 28 illustrate that in order to adjust the electromechanical coupling coefficient  $K^2$  to about 2% or greater,  $\theta$  of the Euler angles and the normalized thickness  $h/\lambda$  of IDT electrodes may be combined as shown in Tables 33 to 42 depending on the normalized thickness  $H/\lambda$  of  $SiO_2$  films.

### TABLE 33

		For $[0.05 \le H/\lambda \le 0.15]$
	When $0 \le \theta \le 48.5$	h/λ does not exist.
25	When $48.5 \le \theta < 49.5$	$h/\lambda$ is 0.04 to 0.0415.
	When $49.5 \le \theta \le 50.5$	$h/\lambda$ is 0.0255 to 0.05.
	When $50.5 \le \theta \le 51.5$	$h/\lambda$ is 0.02 to 0.05.
	When $51.5 \le \theta \le 52.5$	$h/\lambda$ is 0.016 to 0.05.
	When $52.5 \le \theta \le 53.5$	$h/\lambda$ is 0.0135 to 0.05.
	When $53.5 \le \theta \le 54.5$	$h/\lambda$ is 0.011 to 0.05.
30	When $54.5 \le \theta \le 55.5$	$h/\lambda$ is 0.0095 to 0.05.
	When $55.5 \le \theta \le 56.5$	$h/\lambda$ is 0.008 to 0.05.
	When $56.5 \le \theta \le 57.5$	$h/\lambda$ is 0.0065 to 0.05.
	When $57.5 \le \theta \le 58.5$	$h/\lambda$ is 0.0055 to 0.05.
	When $58.5 \le \theta \le 122.5$	$h/\lambda$ is 0.005 to 0.05.
	When $122.5 \le \theta \le 123.5$	$h/\lambda$ is 0.0055 to 0.05.
35	When $123.5 \le \theta \le 124.5$	$h/\lambda$ is 0.007 to 0.05.
33	When $124.5 \le \theta \le 125.5$	$h/\lambda$ is 0.0055 to 0.05.
	When $125.5 \le \theta \le 129.5$	$h/\lambda$ is 0.005 to 0.05.
	When $129.5 \le \theta \le 130.5$	$h/\lambda$ is 0.0105 to 0.05.
	When $130.5 \le \theta < 132.5$	$h/\lambda$ is 0.012 to 0.05.
	When $132.5 \le \theta \le 142.5$	$h/\lambda$ is 0.0115 to 0.05.
40	When $142.5 \le \theta < 143.5$	$h/\lambda$ is 0.012 to 0.05.
40	When $143.5 \le \theta < 144.5$	$h/\lambda$ is 0.0125 to 0.05.
	When $144.5 \le \theta < 146.5$	$h/\lambda$ is 0.013 to 0.05.
	When $146.5 \le \theta < 150.5$	$h/\lambda$ is 0.0135 to 0.05.
	When $150.5 \le \theta < 152.5$	$h/\lambda$ is 0.013 to 0.05.
	When $152.5 \le \theta < 154.5$	$h/\lambda$ is 0.005 or 0.013 to 0.05.
	When $154.5 \le \theta < 155.5$	$h/\lambda$ is 0.005 to 0.0055 or 0.013 to 0.05.
45	When $155.5 \le \theta < 156.5$	$h/\lambda$ is 0.005 to 0.0055 or 0.0125 to 0.05.
	When $156.5 \le \theta < 157.5$	$h/\lambda$ is 0.005 or 0.0125 to 0.05
	When $157.5 \le \theta < 158.5$	$h/\lambda$ is 0.005 to 0.0055 or 0.0125 to 0.05.
	When $158.5 \le \theta \le 159.5$	h/λ is 0.005 to 0.006 or 0.0125 to 0.05.
	When $159.5 \le \theta < 160.5$ When $160.5 \le \theta < 161.5$	h/λ is 0.005 or 0.0125 to 0.05. h/λ is 0.005 to 0.0055 or 0.0125 to 0.05.
	When $161.5 \le \theta < 161.5$ When $161.5 \le \theta < 162.5$	h/λ is 0.005 to 0.0053 or 0.0125 to 0.05.
50	When $161.5 \le \theta < 162.5$ When $162.5 \le \theta < 163.5$	h/λ is 0.005 to 0.0065 or 0.0125 to 0.05. h/λ is 0.005 to 0.0055 or 0.0125 to 0.05.
	When $162.5 \le \theta < 103.5$ When $163.5 \le \theta < 171.5$	h/λ is 0.0125 to 0.005.
	When $171.5 \le \theta < 171.5$ When $171.5 \le \theta < 172.5$	h/λ is 0.0125 to 0.03. h/λ is 0.0125 to 0.0485.
	When $171.5 \le 0 < 172.5$ When $172.5 \le \theta < 173.5$	h/λ is 0.0125 to 0.0485.
	When $172.5 \le \theta < 173.5$ When $173.5 \le \theta < 174.5$	h/λ is 0.0125 to 0.0435. h/λ is 0.0125 to 0.042.
	When $173.5 \le 0 < 174.5$ When $174.5 \le 0 < 175.5$	h/λ is 0.0125 to 0.042.
55	When $174.5 \le 0 < 175.5$ When $175.5 \le 0 < 176.5$	h/λ is 0.0125 to 0.032.
	When $176.5 \le \theta < 180$	$h/\lambda$ is 0.0123 to 0.032.
	WHCH 170.5 S 0 \ 180	11// 18 0.013 to 0.0143.
	·	<u>-                                    </u>

### TABLE 34

-	For [0.15	$\leq H/\lambda \leq 0.25$
	When $0 \le \theta \le 0.5$	h/λ is 0.01 to 0.0345.
	When $0.5 \le \theta \le 1.5$	$h/\lambda$ is 0.014 to 0.0285.
	When $1.5 \le \theta < 45.5$	h/λ does not exist.
65	When $45.5 \le \theta < 46.5$	$h/\lambda$ is 0.0235 to 0.05.
	When $46.5 \le \theta < 47.5$	$h/\lambda$ is 0.0165 to 0.05.

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TABLE 34-continued  For $[0.15 \le H/\lambda < 0.25]$			TABLE 38	
		_	For [0.55	≤ H/λ < 0.65]
When $47.5 \le 6 < 48.5$ When $48.5 \le 6 < 49.5$ When $49.5 \le 6 < 130.5$ When $130.5 \le 6 < 131.5$ When $131.5 \le 6 < 132.5$ When $132.5 \le 6 < 142.5$ When $142.5 \le 6 < 144.5$ When $144.5 \le 6 < 148.5$ When $148.5 \le 6 < 157.5$	h/ $\lambda$ is 0.0115 to 0.05. h/ $\lambda$ is 0.008 to 0.05. h/ $\lambda$ is 0.005 to 0.05. h/ $\lambda$ is 0.006 to 0.05. h/ $\lambda$ is 0.007 to 0.05. h/ $\lambda$ is 0.0075 to 0.05. h/ $\lambda$ is 0.008 to 0.05. h/ $\lambda$ is 0.0085 to 0.05. h/ $\lambda$ is 0.008 to 0.05.	5	When $0 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$ When $40.5 \le \theta < 180$	h/ $\lambda$ is 0.005 to 0.045. h/ $\lambda$ is 0.006 to 0.045. h/ $\lambda$ is 0.0115 to 0.045. h/ $\lambda$ is 0.015 to 0.045. h/ $\lambda$ is 0.044 to 0.045. h/ $\lambda$ is 0.026 to 0.045. h/ $\lambda$ is 0.0155 to 0.045. h/ $\lambda$ is 0.005 to 0.045. h/ $\lambda$ is 0.009 to 0.045.
When $157.5 \le 0 < 166.5$ When $166.5 \le 0 < 169.5$	h/ $\lambda$ is 0.0075 to 0.05. h/ $\lambda$ is 0.007 to 0.05.			
When $169.5 \le \theta < 170.5$ When $170.5 \le \theta < 171.5$	h/ $\lambda$ is 0.0065 to 0.05. h/ $\lambda$ is 0.007 to 0.05.	15	TAI	BLE 39
When $171.5 \le \theta \le 172.5$ When $172.5 \le \theta \le 175.5$	$h/\lambda$ is 0.0075 to 0.05. $h/\lambda$ is 0.008 to 0.05.		For [0.65	$\leq H/\lambda < 0.75$
When 175.5 $\leq \theta < 176.5$ When 176.5 $\leq \theta < 177.5$ When 177.5 $\leq \theta < 178.5$ When 178.5 $\leq \theta < 179.5$ When 179.5 $ [M5]  \leq \theta < 180$	h/λ is 0.008 to 0.0485. h/λ is 0.0085 to 0.0455. h/λ is 0.0085 to 0.0425. h/λ is 0.0085 to 0.0385. h/λ is 0.009 to 0.0345.	20	When $0 \le \theta < 7.5$ When $7.5 \le \theta < 8.5$ When $8.5 _{LM61} \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$	h/λ is 0.005 to 0.045. h/λ is 0.005 to 0.0435. h/λ is 0.005 to 0.0385. h/λ is 0.009 to 0.032. h/λ does not exist. h/λ is 0.0305 to 0.045. h/λ is 0.0105 to 0.045. h/λ is 0.0105 to 0.045. h/λ is 0.0055 to 0.045.
TABL	E 35		When $40.5 \le \theta < 180$	h/λ is 0.005 to 0.045.
For [0.25 ≤ ]	-			
$\begin{array}{llllllllllllllllllllllllllllllllllll$	30	TABLE 40  For $[0.75 \le H/\lambda < 0.85]$		
	35	When $0 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 35.5$ When $35.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 180$	h/λ is 0.005 to 0.045. h/λ is 0.005 to 0.0405. h/λ is 0.009 to 0.035. h/λ is 0.017 to 0.023. h/λ does not exist. h/λ is 0.042 to 0.045. h/λ is 0.0245 to 0.045. h/λ is 0.014 to 0.045. h/λ is 0.0075 to 0.045. h/λ is 0.005 to 0.045.	
TABL	.E 36	40		
For [0.35 ≤ H/λ < 0.45]			TABLE 41	
When $0 \le \theta \le 2.5$ When $2.5 \le \theta \le 3.5$ When $3.5 \le \theta \le 4.5$ When $4.5 \le \theta \le 5.5$ When $5.5 \le \theta \le 6.5$ When $6.5 \le \theta \le 7.5$ When $7.5 \le \theta \le 39.5$ When $39.5 \le \theta \le 40.5$ When $40.5 \le \theta \le 41.5$ When $41.5 \le \theta \le 42.5$ When $42.5 \le \theta \le 43.5$ When $43.5 \le \theta \le 180$	h/λ is 0.005 to 0.045. h/λ is 0.005 to 0.0475. h/λ is 0.005 to 0.044. h/λ is 0.005 to 0.044. h/λ is 0.005 to 0.0355. h/λ is 0.005 to 0.029. h/λ does not exist. h/λ is 0.0355 to 0.05. h/λ is 0.021 to 0.05. h/λ is 0.0350 to 0.05. h/λ is 0.008 to 0.05. h/λ is 0.008 to 0.05.	45 —	For [0.85] When $0 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 35.5$ When $35.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 39.5$ When $39.5 \le \theta < 180$	$ = H/\lambda < 0.95] $ $h/\lambda \text{ is } 0.005 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.007 \text{ to } 0.0415. $ $h/\lambda \text{ is } 0.01 \text{ to } 0.036. $ $h/\lambda \text{ is } 0.018 \text{ to } 0.0255. $ $h/\lambda \text{ does not exist.} $ $h/\lambda \text{ is } 0.037 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.0215 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.012 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.012 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.006 \text{ to } 0.045. $ $h/\lambda \text{ is } 0.005 \text{ to } 0.045. $
		— <sub>55</sub> _	TABLE 42	
TABLE 37		_	For $[0.95 \le H/\lambda \le 1.00]$	
For $[0.45 \le H/\lambda < 0.55]$		_	When $0 \le \theta \le 7.5$ When $7.5 \le \theta \le 8.5$	$h/\lambda$ is 0.005 to 0.04. $h/\lambda$ is 0.007 to 0.04.
When $0 \le \theta < 7.5$ When $7.5 \le \theta < 8.5$ When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 38.5$ When $9.5 \le \theta < 39.5$ When $39.5 \le \theta < 40.5$ When $41.5 \le \theta < 180$	h/λ is 0.005 to 0.045. h/λ is 0.006 to 0.045. h/λ is 0.0105 to 0.045. h/λ is 0.0455 to 0.045. h/λ is 0.0265 to 0.045. h/λ is 0.016 to 0.045. h/λ is 0.016 to 0.045.	60	When $8.5 \le \theta < 9.5$ When $9.5 \le \theta < 10.5$ When $10.5 \le \theta < 11.5$ When $11.5 \le \theta < 35.5$ When $35.5 \le \theta < 36.5$ When $36.5 \le \theta < 37.5$ When $37.5 \le \theta < 38.5$ When $38.5 \le \theta < 180$	h/λ is 0.009 to 0.04. h/λ is 0.012 to 0.04. h/λ is 0.02 to 0.04. h/λ does not exist. h/λ is 0.034 to 0.04. h/λ is 0.0195 to 0.04. h/λ is 0.0105 to 0.04. h/λ is 0.005 to 0.04.

In Experiments 1 to 3, the IDT electrodes were made of Au. The IDT electrodes may be made of another metal. When the IDT electrodes are made of a metal other than Au, the range of (h/ $\lambda$ )×a may be selected as the range of h/ $\lambda$  of the IDT electrodes made of Au for the normalized thickness h/ $\lambda$ . That is, the range of (h/ $\lambda$ )×a may preferably be selected as shown in Tables 1 to 20. Herein, a represents the ratio of the density of a metal of the IDT electrodes to the density of Au.

The reason why the range of  $(h/\lambda) \times a$  may be used instead of the range of  $h/\lambda$  when the IDT electrodes are made of a metal other than Au is that substantially the same boundary acoustic wave velocity as the boundary acoustic wave velocity of the IDT electrodes made of Au is obtained by normalizing the thickness of the IDT electrodes as applied to the density of the metal

When the IDT electrodes are made of a metal other than Au,  $(h/\lambda)$ ×a may preferably be used instead of  $h/\lambda$ , which is used for Au. Electrodes including the IDT electrodes may each include a metal laminate film formed by stacking a plurality of metal layers, which are preferably each made of a corresponding one of Pt or Al. The metal laminate film preferably includes Pt layers and Al layers as main electrode layers, for example. This enables the resistance of electrode fingers to be reduced and, therefore, enables properties thereof to be improved. The Pt layers may preferably be disposed on the piezoelectric substrate side or the first medium layer side. A Pt layer may preferably be disposed between two of the Al layers.

The metal laminate film, which is formed by stacking the metal layers, preferably includes a metal layer abutting the piezoelectric substrate, a metal layer abutting the first medium layer, and a metal layer which is arranged at at least one location between the metal layers abutting the piezoelectric substrate and the first medium layer and which is made of at least one material selected from the group consisting of Ti, Ni, and NiCr, for example. The metal layer provides increased adhesion to the piezoelectric substrate, increased adhesion to the first medium layer, and/or increased adhesion between the metal layers.

Experiments performed by the inventors have verified that substantially the same results are obtained even if  $\phi$  and  $\psi$  of Euler angles slightly shift from  $0^\circ$  with respect to Euler angles  $(0^\circ, \theta, 0^\circ)$ . That is, when  $\phi$  is within the range of about  $0^\circ \pm 5^\circ$  and  $\psi$  is within the range of about  $0^\circ \pm 25^\circ$ , substantially the same results are obtained.

The Euler angles of LiTaO $_3$  may be Euler angles equivalent in boundary acoustic wave properties from Equation (A) below.

$$\begin{split} F(\varphi,\theta,\psi) &= F(60^\circ + \varphi, -\theta, \psi) & \text{Equation (A)} \\ &= F(60^\circ - \varphi, -\theta, 180^\circ - \psi) \\ &= F(\varphi, 180^\circ + \theta, 180^\circ - \psi) \\ &= F(\varphi,\theta, 180^\circ + \psi) \end{split}$$

Experiment 4

Boundary acoustic wave devices were prepared in substantially the same manner as described in Experiment 1, except that IDT electrodes were made of Pt films and the normalized thickness h/ $\lambda$  of the IDT electrodes was adjusted such that (h/ $\lambda$ )×a was about 3.0%, about 5.0%, or about 6.0%. The normalized thickness H/ $\lambda$  (%) of SiO<sub>2</sub> was about 40%. The Euler angles of LiTaO<sub>3</sub> were (0°, 132°, 0°). FIGS. 7 to 9 show the impedance Smith charts of the boundary acoustic wave

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devices, in which the normalized thickness of the Pt films was about 3.0%, about 5.0%, or about 6.0%.

As is clear from FIGS. 7 to 9, a transverse-mode ripple can be effectively suppressed by reducing  $(h/\lambda)\times a$  from about 6.0% to about 5.0% or less.

Therefore, it is clear that in a structure including first and second medium layers disposed on LiTaO<sub>3</sub>, a transverse-mode ripple can be effectively suppressed by adjusting the normalized thickness ( $h/\lambda$ )×a of IDT electrodes to about 5% or less, that is, about 0.05 or less.

In each of Experiments 1 to 4, the first medium layer 3 was made of  $SiO_2$  and the second medium layer 4 was made of SiN. Substantially the same results were obtained when using SiON and AIN, instead of SiN.

Therefore, a second medium layer **4** can preferably be formed from at least one material selected from the group consisting of SiN, SiON, AlN, AlO, Si, SiC, diamond-like carbon, and polysilicon, for example.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

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- 1. A boundary acoustic wave device comprising:
- a piezoelectric substrate made of single-crystalline LiTaO<sub>3</sub>;
- a first medium layer disposed on the piezoelectric substrate and made of a dielectric material;
- a second medium layer disposed on the first medium layer and made of a dielectric material having a sound velocity different from a sound velocity of the dielectric of the first medium layer; and
- at least one interdigital electrode disposed at a boundary between the piezoelectric substrate and the first medium layer and made of a metal; wherein
- the sound velocity of the first medium layer is less than a sound velocity of LiTaO<sub>3</sub>, the sound velocity of the second medium layer is greater than the sound velocity of LiTaO<sub>3</sub>, and the inequality (h/λ)xa≤0.05 is satisfied, where H is the thickness of the first medium layer, h is the thickness of the interdigital electrode, λ is a period of electrode fingers of the interdigital electrode, and a is a ratio of a density of the metal defining the interdigital electrode to a density of Au, and
- when the LiTaO<sub>3</sub> has Euler angles (0°±5°,  $\theta$ , 0°±25°), the normalized thickness (h/ $\lambda$ )×a of the interdigital electrode is within one of ranges shown in Tables 16 and 17 with respect to the value of H/ $\lambda$  and the value of  $\theta$ :

TABLE 16

For $[0.55 \le H/\lambda < 0.65]$				
When $0 \le \theta < 8.5$	(h/λ) X a is 0.005 to 0.045.			
When $8.5 \le \theta < 9.5$	(h/λ) X a is 0.006 to 0.045.			
When $9.5 \le \theta < 10.5$	(h/λ) X a is 0.0115 to 0.045.			
When $10.5 \le \theta < 36.5$	(h/λ) X a is 0.0455 to 0.045.			
When $36.5 \le \theta < 37.5$	(h/λ) X a is 0.044 to 0.045.			
When $37.5 \le \theta < 38.5$	(h/λ) X a is 0.026 to 0.045.			
When $38.5 \le \theta < 39.5$	$(h/\lambda)$ X a is 0.0155 to 0.045.			
When $39.5 \le \theta < 40.5$	$(h/\lambda)$ X a is 0.009 to 0.045.			
When $40.5 \le \theta < 180$	$(h/\lambda)$ X a is 0.005 to 0.045.			

TABLE 17

For $[0.65 \le H/\lambda \le 0.75]$				
When $0 \le \theta < 7.5$	$(h/\lambda) X$ a is 0.005 to 0.045.			
When $7.5 \le \theta \le 8.5$	$(h/\lambda)$ X a is 0.005 to 0.0435.			
When $8.5 _{[M8]} \le \theta \le 9.5$	$(h/\lambda)$ X a is 0.005 to 0.0385.			
When $9.5 \le \theta \le 10.5$	$(h/\lambda)$ X a is 0.009 to 0.032.			
When $10.5 \le \theta \le 36.5$	$(h/\lambda)$ X a does not exist.			
When $36.5 \le \theta < 37.5$	$(h/\lambda)$ X a is 0.0305 to 0.045.			
When $37.5 \le \theta < 38.5$	$(h/\lambda)$ X a is 0.0185 to 0.045.			
When $38.5 \le \theta < 39.5$	$(h/\lambda)$ X a is 0.0105 to 0.045.			
When $39.5 \le \theta < 40.5$	$(h/\lambda)$ X a is 0.0055 to 0.045.			
When $40.5 \le \theta \le 180$	$(h/\lambda)$ X a is 0.005 to 0.045.			

- 2. The boundary acoustic wave device according to claim 15 1, wherein the dielectric material of the first medium layer primarily includes SiO<sub>2</sub>.
- 3. The boundary acoustic wave device according to claim 1, wherein the dielectric material of the second medium layer primarily includes at least one material selected from the group consisting of SiN, SiON, AlN, AlO, Si, SiC, diamond-like carbon, and polysilicon.
- **4**. The boundary acoustic wave device according to claim **1**, wherein the Euler angles of the LiTaO<sub>3</sub> are Euler angles <sub>25</sub> equivalent in boundary acoustic wave properties from Equation (A):

$$F(\varphi, \theta, \psi) = F(60^{\circ} + \varphi, -\theta, \psi)$$
 Equaiton (A)  

$$= F(60^{\circ} - \varphi, -\theta, 180^{\circ} - \psi)$$
  

$$= F(\varphi, 180^{\circ} + \theta, 180^{\circ} - \psi)$$
  

$$= F(\varphi, \theta, 180^{\circ} + \psi).$$

- 5. The boundary acoustic wave device according to claim 1, wherein the interdigital electrode is made of Pt.
- 6. The boundary acoustic wave device according to claim 1, wherein the interdigital electrode includes an Al film disposed on a first medium layer side and a Pt film disposed on a piezoelectric substrate side.
- 7. The boundary acoustic wave device according to claim 1, wherein the interdigital electrode includes a Pt film disposed on a first medium layer side and an Al film disposed on a piezoelectric substrate side.
- 8. The boundary acoustic wave device according to claim 1, wherein the interdigital electrode includes a metal laminate film including a first metal layer abutting the piezoelectric substrate, a second metal layer abutting the first medium layer, and a third metal layer which is arranged in at least one location between the first and second metal layers, and the third metal layer being made of at least one material selected from the group consisting of Ti, Ni, and NiCr.

\* \* \* \* \*